PREFACE TO VOL. V.

WITH the issue of this Quarterly No XXII, the Fifth Volume of the Second Series of Professional Papers on Indian Engineering is brought to a close and the complete series (1st and 2nd) of these records on engineering experience in this country, now amounts to *twelve* large Volumes, containing much valuable information on a variety of subjects connected with every branch of the profession as occurring in India.

This Volume is as varied in its contents as any of its predecessors, and contains articles, both practical and theoretical, in most departments of Engineering Of the *thirty-five* papers therein contained, the largest number devoted to one subject is *six*, and these relate to manufacture, experiments, or machinery, in connection with *Cements* and *Puzzolanas*, the attention to which important materials is producing a marked improvement in building generally throughout the Country *Railway* matters form the subject of *four* papers the claims of the 'Central-Ladder-rail' system are again brought before the readers of this publication, as this, or some similar system, must ere long engage the attention of Indian Engineers in connection with the Himalayas, Nilgherries, and perhaps the ranges bounding our North-Western frontier *Irrigation*, and its cognate subject, *Drainage*, occupy *four* articles In the coming days of retrenchment, or at least increased economy, in Public Works, the suggestions contained in Mr Beresford's paper on the 'Duty of Water' deserve the careful attention of those on whom rests the responsibility of aligning canals and their distributaries, and the irrigation of different soils and varying tracts of country

The Construction of Roofs in wood or iron is treated of in *five* articles, some theoretical, others practical. In the former category may be specially noticed, the paper No. CLXXXIX on "Continuous Uniform Beams," a most valuable contribution (by Captain Allan Cunningham, R. E.) to the Mathematics of Engineering, in which the problem is presented in a new and comparatively simple form, novel at least to English Students. The specifications of roofs and roof coverings (extracted from Mr. J. P. C. Anderson's book of Specifications) come under the second category; they will be found useful to builders in most parts of India, and can be accepted as reliable, being based on considerable and varied Indian experience.

Three papers are devoted to *Bridge* building: to one of these (No. CCIII) giving a description of the St. Joseph Bridge, exception might be taken on the score of the work being American, not Indian: but the conditions of the Missouri river in that locality are so similar in many respects to those of the larger rivers of the Punjab, that the description of the river-training works and the foundation details of the American Bridge, will prove interesting and instructive to the Indian Engineer: and the form of the bridge itself is somewhat novel, and worthy of study as equally applicable to structures in this Country.

One paper devoted to the *Harbour* now under construction at Madras, is valuable, as discussing a class of works as yet but little studied by the profession in India, but for which a considerable field exists on the coasts of this country with its extensive sea board. The paper in question views the problem in two very distinct lights: and during the prosecution of the work, the conflicting opinions of the friends and foes of the present scheme will receive illustration, very instructive to those who watch the course of events.

Designs of Buildings are illustrated and described in *two* articles of this present Volume. In each case the architects are natives of India; one, Rai Kunhya Lál Bahadur is an Engineer of long and varied experience, and of high standing in the P. W. Department: the other who is by profession a draftsman in a (Railway)

Chief Engineer's office, has already twice distanced all rivals in competing for prizes offered to the furnisher of the best designs for works of an oriental character. Teekaram's prize design for the Alwar Rajah's Railway Station, was published in the IVth Volume of this Series and his design for the New Canning College at Lucknow,—which won the prize, and was accepted for adoption by the Committee,—is given in Paper No. CCX. of this new Volume.

The remaining *nine* papers are on various subjects the most notable perhaps being an interesting article (No. CC) on *Dredgers and Dredging*, by Mr. J. W. Bains, M. Inst. C.E

This series of papers will be continued in the same form, and under the same terms, as heretofore, in a VIth Volume, of which the first issue, Quarterly Number XXIII. will be published in January 1877.

A. M. L.

INDEX TO VOL. V.

[SECOND SERIES.]

LIST OF PLATES

Photograph

Lithographs

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the walls, to be large, measuring $9'' \times 4\frac{1}{2}'' \times 3''$, those for the rest of the work to be of the usual size of small bricks used at Lahore

Inside to be lime plastered and whitewashed, and outside to be dressed, and rubbed smooth, of a light red stone color

The flooring to be second class tiled, tiles $12'' \times 12'' \times 3''$, set in lime mortar, with close joints, over 6 inches of concrete.

The roofs of Senate Hall, Library and Registrar's Room, to be slated (first class), carried over trusses of deodar wood, having a light and ornamental boarded ceiling, painted white, with blue edgings. Round openings 12 inches diameter fitted with iron wire netting $\frac{5}{8}$-inch mesh, to be left in the ceiling at every 10 or 12 feet for purposes of ventilation

The roof of all the remaining rooms, including verandahs, to be carried over beams and burgahs of deodar wood, overlaid with second class terrace

The dimensions of the trusses, beams, and burgahs, to be as per calculations accompanying Wall plates under tie-beams of trusses to be $6'' \times 4''$, under beams

Over 10 feet bearing,	$5'' \times 4''$
Under beams 10 feet bearing,	$4'' \times 3''$
And under burgahs,	$3'' \times 2\frac{1}{2}''$
Straps for the trusses to be	$2'' \times \frac{1}{2}''$
Bolts,	$\frac{3}{4}''$ diameter
Screw nuts,	$2\frac{1}{2}'' \times 2\frac{1}{2}'' \times 1\frac{1}{4}''$

Doors and windows to have semi-circular glazed fanlights over them

The outer doors to be one-fourth panelled and three-fourths glazed, and the inner ones to be entirely panelled Windows to be entirely glazed.

Doors to be 2 inches thick, windows $1\frac{3}{4}$ inches thick, door frames $4\frac{1}{2}'' \times 4\frac{1}{2}''$, window frames $4'' \times 4''$ After completion of work all spare materials to be removed, the ground outside to be trimmed, and the place rendered neat and tidy, to be made over to the Registrar of the Punjab University College Proper approaches 20 feet wide, with syphons over the rajbaha in front of the building, to be made, and a space of 12 feet width all round the building to be metalled with broken bricks 6 inches thick, with a slope of 3 inches outwards, for the proper discharge of rain water

The compound to be enclosed with a wooden railing or hedge

A house for the chowkeedar $10' \times 10'$ to be built at the back of the building.

No CLXXX

SENATE HALL FOR PUNJAB UNIVERSITY COLLEGE, LAHORE

[*Vide* Plates I, II and III]

Designed and constructed by RAI KUNHYA LAL, A I C E., *Exec. Engineer, Lahore.*

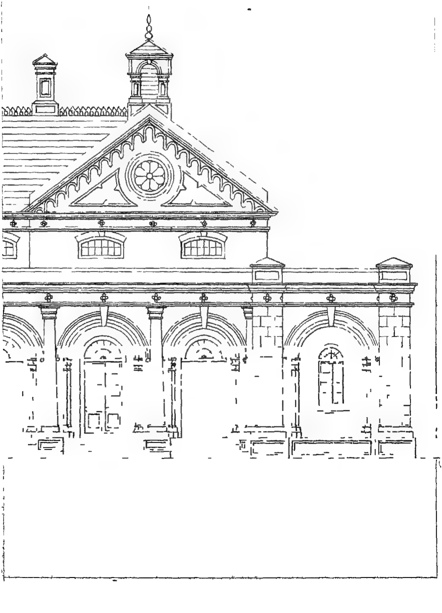
THERE being no building available at Lahore sufficiently large for the requirements of the Senate of the Punjab University College, a new building is constructed, as per plan shown in *Plate* III, which has been drawn up in communication with, and approved by, the Registrar and the President of the Executive Committee of the Senate of the Punjab University College.

The cost of the building is met from a donation of Rs 25,000* (made by H H the Nawab of Bhawálpur), and the interest accruing thereon, since the donation was vested in Government Securities, and the building is to bear the name of the Donor in the inscription in the Front, (*see* elevation of building, *Plate* I)

The building is constructed according to the following Specification —

The foundation to consist of concrete, 3 feet deep, overlaid with 2 feet of pucka masonry Concrete to consist of one part of kunkur lime, one part of lime siftings, and one part of broken bricks, well mixed and consolidated All masonry (foundation, plinth and superstructure) to be of pucka bricks laid in good lime mortar, having six to ten per cent of stone lime mixed in it for pillars, arches, mouldings, and cornice work The bricks required for pillars and arches, and the exposed parts of all

* Which, with the interest accruing thereon, now amounts to about Rs 30,000



General Remarks

The building to be constructed in a workmanlike manner—and good materials approved by the officer in charge of the work to be used All bad materials rejected by the above officer to be removed from the work

The wood to be well seasoned sound deodar, free from large knots and flaws

The bricks to be thoroughly burnt, of a cherry red color, giving a clear ringing sound on being struck

The lime to be fresh oopla burnt for plain work and plaster, and wood burnt for pillars, arches, and cornice

Calculations of Strength of Beams, &c

Beams —Beams $17\frac{1}{2}$ feet bearing

Interval from centre to centre $= \frac{23}{5} = 4{\cdot}6$ feet

Weight acting at centre of each beam, at 100 lbs. per superficial foot $= \frac{4{\cdot}6 \times 17\frac{1}{2} \times 100}{2} = 4{,}020$ lbs

Strength of beam $16'' \times 10'' = \frac{300 \times 16^2 \times 10}{17{\cdot}5 \times 10} = 4{,}388$ lbs

Beams —Beams 16 feet bearing

Interval from centre to centre $= \frac{26}{6} = 4{\cdot}33$ feet

Weight acting at centre of each beam, at 100 lbs per superficial foot $= \frac{4{\cdot}33 \times 16 \times 100}{2} = 3{,}466$ lbs.

Strength of beam $16'' \times 10'' = \frac{300 \times 16^2 \times 10}{16 \times 10} = 4{,}800$ lbs.

Beams.—Beams 12 feet bearing

Interval from centre to centre = 6 feet

Weight acting at centre of each beam, at 100 lbs per superficial foot $= \frac{6 \times 12 \times 100}{2} = 3{,}600$ lbs.

Strength of beam $14'' \times 8'' = \frac{14^2 \times 8 \times 300}{10 \times 12} = 3920$ lbs

Beams —Beams 10 feet bearing

Interval varying from 3 to 6 feet

Strength of beam $12'' \times 6'' = \frac{144 \times 6 \times 300}{10 \times 10} = 2{,}592$ lbs.

This agrees to an interval of about 5 feet In verandah, few intervals exceed 5 feet, but as the coefficient of 300 is much on the safe side, therefore $12'' \times 6''$ would suffice for all rooms 10 feet span

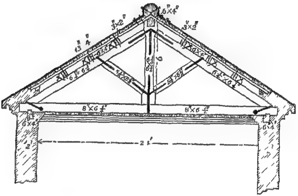
Burgahs.—Bearing varying from 3 to 6 feet

Strength of a burgah $4'' \times 3''$ of 5 feet bearing $= \frac{4^2 \times 3 \times 300}{10 \times 5}$ $= 288$ lbs

Weight acting at centre of each burgah $= \frac{5 \times 100 \times 1}{2} =$ 250 lbs

Thus, all burgahs may be of this dimension, even where the bearing approaches to 6 feet, as the coefficient of 300 is much on the safe side

Section of Truss for 24 feet span



Span $=$ 24 feet.
Rise $=$ 6 "
Interval $=$ 5 "

Weight of roofing, acting vertically $= 100$ lbs per square foot
Allowance for weight of truss $= 20$ " "

Total, 120 " "

Wind pressure, acting normal to the roof surface $= 30$ lbs

Notations used in formulæ

$W =$ Weight (in pounds) of roofing on one Truss
$W' =$ Normal wind pressure.
$i =$ Inclination of roof.
$R =$ Normal reaction $\frac{3\,W' \sec^2 I}{4} = \frac{3}{4} \times 2{,}010 \times \left(\frac{13 \cdot 4}{12}\right)^2 = 1{,}885$ lbs
$W = 13 \cdot 4 \times 2 \times 5 \times 120 = 16{,}080$ lbs
$W' = 13 \cdot 4 \times 5 \times 30 = 2{,}010$ lbs.

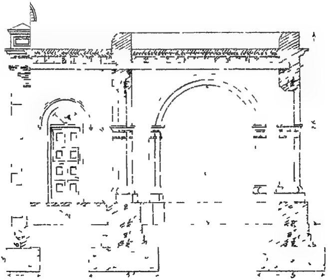


Table of Scantlings, showing formulæ, stress, and dimensions

Names of pieces	Formulæ		Stress in pounds		Character of Stress	Total of Stress	Formulæ for Dimension	Dimensions according to formulæ	Dimensions given	Remarks
	Vertical	Normal	Vertical	Normal						
Rafter, . ..	$\frac{3}{8}$ W cosec i	$\left(R - \frac{W}{4}\right)$ cot i	13,467	2,766	Thrust	16,233	$\frac{\text{Stress}}{\frac{5}{8}\text{ of }500} = \text{area.}$	Area = 39 sq in	$6\frac{1}{4}'' \times 6\frac{1}{4}''$	
Tie-beam, ..	$\frac{3}{8}$ W cot i	$\left(R - \frac{W}{4}\right)$ cosec i	12,060	3,082	Tension.	15,142	$\frac{\text{Stress}}{700} = \text{area}$	Area = 22	$8'' \times 6\frac{1}{4}''$	
King-post, ..	$\frac{W}{4}$	$\frac{W}{4}$ sec i.	4,020	563	Tension	4,583	$\frac{\text{Stress}}{700} = \text{area.}$	Area = 7	$6\frac{1}{4}'' \times 6\frac{1}{4}''$	
Strut,	$\frac{W}{8}$ cosec i.	$\frac{W}{2}$ cosec 2 i	4,489	1,256	Thrust	5,745	$\frac{\text{Stress}}{\frac{1}{4}\text{ of }500} = \text{area.}$	Area = 23	$5\frac{1}{2}'' \times 5\frac{1}{2}''$	
Purlins, .	..	.	$\frac{5 \times 3 \times 100}{2} = 750$	..	Transverse	750	$\frac{6^2 \times 4 \times 300}{10 \times 5} = 864$	$6'' \times 4''$	$6'' \times 4''$	
Battens, ..	.	.	..	..				.	$3'' \times 2''$	
Ridge pole, ..	.	.	..	.	..	.	..	..	$6'' \times 4''$	
Planking under the slates, .	.	..	..	..	..	..	.	.	1″ thick	

Abstract of Cost of Constructing a Senate Hall at Lahore, for the University College, Punjab

c ft		RS
43,425	Excavation in foundation and filling in plinth, at Rs 2 8 per 100,	109
16,941	Concrete work in foundation, at Rs 12 4 per 100, .	2,075
7,647 54	Burnt bricks in lime mortar in foundation, at Rs 16 per 100,	1,224
2,651	" " in interior plinth, at Rs 18 4 per 100, ..	484
802	" " in exterior plinth, at Rs 35 per 100, . ..	281
714	Brick-on-edge work in steps and exterior plinth, at Rs 40 per 100,	286
1,752	Brick plain work in steps and exterior plinth, at Rs 24 per 100,	420
5,921	Brick in superstructure, both sides dressed, at Rs 40 per 100, ..	2,368
13,338	Brick in superstructure, one side dressed, at Rs 35 per 100,	4,668
16,962	Brick in superstructure, plain work, at Rs 24 per 100, .. .	4,071
r ft.		
1,014	Outer cornices, at Rs 0 6 0 per foot, ...	380
624	Inner cornices, at Rs 0-4-6 per foot, ...	175
No		
5	Fire places, at Rs 22 each, ...	110
s ft		
7,595	Tiled floor, 2nd class, at Rs 10 per 100, . . .	760
4,867	Flat terrace roof covering, 2nd class, at Rs 8 per 100, .. .	389
19,310	Lime plaster, 2nd class, at Rs 3-9 0 per 100, .	687
19,310	Whitewashing, at Rs 0 4 0 per 100, . .	48
5,466	Slate roof covering, including ridging and zinc sheet, &c , at Rs 40 per 100, ...	2,186
c ft		
1,099	Deodar wood for trusses, at Rs 2-12-0 per foot, .	3,022
205	" beams from 18 to 20 feet long, at Rs 2 12 0 per foot,	564
355 52	" beams from 12 to 14 feet long, at Rs 1-13 0 per foot,	645
644 17	" burgahs and wall plates, at Rs 1-4 0 per foot, ..	805
s. ft		
3,941	Ceiling, at Rs 0 4 0 per foot, . .	985
5,466	Planking, at Rs 0-2-0 per foot, . . .	683
No		
26	Sunshades, at Rs 5 4 0 each, ...	136
s ft.		
744	Doors, ¼th panelled and ¾ths glazed, at Rs 1 per foot,	744
384	Panelled doors, at Rs 1 per foot, .	384
868	Glazed doors and windows, at Rs 0-12 0 per foot, .	646
mds srs		
80 20	Wrought iron work, at Rs 12 8 0 per maund, . . .	1,009
s ft.		
1,989	Spirit varnish of doors and windows, at Rs 2 per 100,	40
1,685	Glazing doors and windows, at Rs 0 4 0 per foot, . .	421
3,949	Painting white, with blue edging, at Rs 4 per 100,	158
	Carried forward,	30,963

		Rs
	Brought forward, .	30,963
c ft		
742	Kucha pucka masonry, including inner kucha plaster, at Rs 8 per 100,	59
s ft		
520	Outer pucka plaster, at Rs 4 per 100,	21
100	Mud roof covering, 1st class, at Rs 6 per 100,	6
c ft		
14	Burgahs and wall plates for roof, at Rs 1 per foot,	14
6	Beams for wall plates for roof, at Rs 1 8 per foot,	9
s ft		
28	Battened doors, at Rs 0 8 0 per foot,	14
r ft		
800	Fence, round the compound, at Rs 0-2 0 per foot,	100
c ft.		
4,104	Brick metalling of approaches, at Rs 4 per 100,	164
13,850	Earthwork of approaches, at Rs 3 per 100,	42
1,442	Pucka masonry of syphon over the rajbaha in front of building, at Rs 30 per 100,	433
	Levelling and clearing ground,	125
	Inscription in front of building,	100
No		
3	Ventilating shafts, at Rs 165 each,	495
	Total Rupees,	32,545

K L

No CLXXXI.

ARTIFICIAL PUZZOLANA MADE OF BURNT CLAY

[*Vide* Plate IV]

Remarks on Artificial Puzzolana made with Burnt Clay By P DEJOUX, ESQ, *Exec Engineer, Cement Experiments Division*

Dated the 14th July, 1875

Surki —The most common kind of artificial puzzolana, called generally in India "súrki," is made with burnt bricks pounded, more or less

The earth used for making these bricks is composed of fat earth and sand, and the puzzolana thus obtained is of very inferior quality

The practice of not carefully selecting the bricks burnt to the degree required for transforming a clay into an active puzzolana, leads to the cause of the súrki being generally composed of large proportions of inert matter, which does not impart any hydraulicity to the mortar

Puzzolana made with fine or marly clays —Artificial puzzolana ought to be made with either pure clay free from sand (or at any rate not containing more than 5 per cent of it) or with marly clays which contain carbonate of lime

1st *Clays not containing carbonate of lime, and, if any, in small proportions* —Clays are hydratic combinations of silica and alumina

The degree of calcination which transforms them into puzzolana with the maximum of hydraulicity is the same as the calcination required for expelling the water entirely

Therefore to transform a clay into puzzolana, the calcination must be regulated so as to expel the last particle of water without exceeding 1100 to 1300 degrees Fahrenheit This is what Vicat calls "*cuisson normale*" (normal calcination)

2nd *Clays containing more than* 15 *to* 20 *per cent of carbonate of*

lime.—More calcination is necessary in these than the previous ones, so as to decompose the carbonate, and cause the combination of the lime and clay, but the temperature of 1300 to 1500 degrees Farenheit must not be exceeded, consequently it is requisite to calcine them with a slow fire, but much longer than the previous ones.

Therefore it leads to the conclusion that clay requires only slight calcination to be transformed into puzzolana.

Preparing the clay.—It has been noticed that contact with air during the calcination of a puzzolana has great effect on its quality.

This has never been clearly explained, but it is a fact. Consequently, it is necessary to render the clay as porous as possible.

This can be done by adding either some straw or saw-dust to it before either bricks or balls are made with it.

This precaution, however, is only necessary when large bricks or balls are made, but it will be unnecessary if dry clay, as found in its natural state, is used in broken pieces, not exceeding the size of an egg.

Burning.—*1st Mode*. The easiest way of burning puzzolana is obtained by means of a kiln built on the principle of alternate fires.

The annexed (*Plate* IV.,) is the drawing of a small kiln of this description, which I built for experimental purposes.

This design, however, could be enlarged for practical purposes, by increasing each dimension proportionally to the cubical contents required.

When raw clay in form of either bricks or balls (or even in pieces) has been put on the grating A, and the kiln has been loaded, a fire is lighted in the furnace B, and this fire is kept on for a certain number of hours, determined by experience.

Suppose the calcination has taken place for 8 hours, it will be found that after that time while the contents of the portion (*a*) will be well burnt, those of the portion (*b*) being further from the flame will only be half burnt.

The fire is then stopped in furnace B, and lighted in furnace C, and after 8 hours the contents of (*c*) will be found properly calcined, and as (*b*) has now been in fact exposed to the action of a heat not so strong as that to which (*a*) and (*c*) were subject, but which nevertheless lasted for 16 instead of 8 hours only, this portion even will be found well calcined, and the entire contents of the kiln therefore must be found burnt almost to the same degree.

2nd Mode Puzzolana can also be calcined by loading the top part of a lime kiln with the raw clay, and the bottom with lime, and thus it happens while the lime is well burnt, the clay is also calcined to a good degree

This process, however, can be useful when only a small quantity of good puzzolana is required for any special works

3rd Mode Puzzolana is at times burnt in clamps This burning, however, is not only irregular, but a large portion frequently gets overburnt, and besides the puzzolana obtained by this process is inferior in quality

Grinding burnt Puzzolana.—Puzzolana made with any clay gives mortar the maximum of hydraulicity only when it is pulverized into fine powder, otherwise while only a feeble portion acts as puzzolana, the other does as an inert body, much inferior to sand, and consequently the mortar thus obtained is more absorbent and lighter than sand mortar

General remarks *about Puzzolana Mortars*.—*1st* An artificial puzzolana affords always much better results with a fat lime than with a lime yielding a fair degree of hydraulicity

2nd Good ordinary hydraulic lime when mixed with sharp sand, gives after a certain time, superior mortar to any puzzolana mortar, the only advantage of the latter consisting in quicker setting

3rd The cohesion of a puzzolana mortar, being the result of what we may call a chemical combination, will be evidently much increased,—

By the fine state of the lime and puzzolana,

By the drawing as close as possible of these two materials, which will be obtained by a good trituration of the mortar, and

By constant dampness, without which the affinity of one material with the other will not take place, and therefore no combination

4th Puzzolana mortars without the admixture of such a hard substance as sand, are liable from constant dampness to expand, and they act in the opposite manner when left exposed for some time to a dry atmosphere Then they contract, cracks follow, and very often with the exception of the outside crust, they become friable and pulverulent

The only remedy for this is to add a notable proportion of sand (rather coarse) However it may here be said that puzzolana mortars generally afford much better results when immersed always, or exposed to a certain dampness, and not left dry for any length of time.

Chemical action of a Puzzolana —Both puzzolana and lime by intimate combination (chemically speaking) form quite a homogeneous mass, where the lime is no more a body binding together such a hard substance as sand, which keeps exactly both its form and volume the pure lime on the contrary disappears, to give place to a double silicate of lime and alumina

Note 1st Nearly all these remarks are based on the last theory of Vicat on artificial puzzolana, and have proved correct from practical tests and experience

Note 2nd If súrkí is intended only to be used as a substitute for sand, it must be calcined more, but will not require fine grinding

P D

No CLXXXII

INDIAN RAILWAY TRAFFIC.

It is a well-known fact that the traffic on the opened lines of Indian Railways is still in a very undeveloped state, and that while one or two of the most important lines return a fair profit on the capital, that profit is far below what it ought to be, considering the population and natural wealth of the districts through which they run On the other hand, many lines do not earn anything like the interest guaranteed by Government to the shareholders, and more than one does not even pay its working expenses

The result of this state of things is, that the revenues of India are saddled with the payment of something like three millions sterling annually, being the amount required to make good the guaranteed interest—and as this sum represents about the first cost of 60 miles of new railway of the State pattern, it is evident the loss is not a slight one

In the construction of the new State Railways, the Government has wisely profited by the experience derived from the guaranteed lines They have been made with a strict regard to economy, and their management promises to be equally economical, rather too much so in the opinion of many But it is in the further development of traffic, both on them and on the older lines, rather than in cheapness of management, that a fair return for the cost is to be sought, and it is to this important point that I wish to draw attention

Two years ago I submitted two Memoranda to Government on this subject, based chiefly on experience of the American Railways. These were circulated by direction of the Government, with a view of eliciting the opinions of the various railway authorities—with what result I have not heard. But as the subject is a very important one, I venture again to bring it forward here at somewhat greater length, with a view to discussion by those interested in the matter

The chief obstacles to the proper development of the Railway passenger traffic in this country I take to be—*1st*, The dearness of the present fares, *2nd*, The want of facilities for the comfort and convenience of the travelling public

I As regards the first, the assertion will perhaps surprise those who simply compare the mileage rate with that charged in England The third class* rate on the guaranteed lines is $\frac{3}{8}d$ per mile—as against $1d$ in England But the difference in the value of money in the two countries is altogether overlooked, and this difference cannot *at the very lowest* be set down at less than 4 to 1 † That is, where the English workman will have $1s$ to spend on travelling, his Indian brother will only have $3d$ It will therefore appear that the charge of three pies per mile to the Indian third class passenger, is to all intents and purposes equivalent to an English rate of at least $1\frac{1}{2}d$ per mile—a rate which would practically reduce the third class traffic on an English railway to a minimum It is true that on the newly opened State railways, the charge has been reduced to two pies per mile, which is not very much higher than the ordinary English rate of $1d$ But the tendency on English lines is to a much lower fare than this. Excursion trains constantly carry passengers at $\frac{1}{3}d$ per mile, and the late successful results on the Midland Railway show, even in a wealthy country like England, how largely receipts may be increased by cheap fares It is, therefore, with amazement that I read in a late Government report, that "the low rate on the Delhi District (1 4 pies) was "decidedly successful in attracting traffic During the first half of 1874, "when the open line was confined to the section between Delhi and Re-"waree, 635 passengers were on an average carried daily over each mile "of line in one direction or the other On the Agra District (where the "rate was two pies) during the same period, the average number was "250, and although this District was differently circumstanced as regards "trade, and the distribution of the population, still there seemed to be "much in favor of the low fares These fares however were not sufficient "to make the railway pay and passengers were under them carried at a "minimum of profit, if not actually at a loss *It was therefore decided "that they should be raised*" A step which was of course followed immediately by a considerable diminution of traffic

* Third class traffic is alone considered here, because that forms more than $\frac{9}{10}$ths of the whole

† Taking the average wage of the common laborer in the two countries ($2\frac{1}{2}$ as $= 3\frac{3}{4}d.$ and $2s$) which seems a fair standard of comparison, it will be seen that 6 to 1 is nearer the mark.

Whoever wrote the above report, would do well to read the following —

"It is a remarkable fact that those Companies which charge the high-"est fares generally pay the smallest dividends Take for instance the "case of the Great Eastern Company, so celebrated for high fares and "low dividends, or more strictly speaking *no* dividends As a view of "the other side of the question, take the case of the North Eastern which "has the lowest fares and highest dividend of any large English Rail-"way" [*Fortnightly Review, July* 1875]

It should be remembered that passengers consist—1*st*, of those who *must* travel (unless the cost be altogether prohibitary), 2*ndly*, of those who will travel *if they can afford it*—not otherwise—and that the number of these latter greatly exceeds the former It is obvious that if Railway fares are regulated simply with an eye to the former class, they will be made as high as possible, if the latter class are to be considered, then the tendency will certainly be to lower them to a minimum, based on a careful calculation of the lowest* profit at which the individual passenger can be carried Even if the net result to the Railway were the same in either case, it is obvious that the convenience to the public is a strong element in the comparison

One very absurd argument which has been more than once adduced in justification of the high fares in Indian lines may just be noticed It is said that, as the skilled labor and material employed in the construction of these lines has to be imported from England, *of course* higher rates have to be charged to passengers Would any one in England, who wished to travel (say) from London to Liverpool by the Great Western, be persuaded to pay a higher fare to go by this line on the ground that it had cost more to make it than the North Western line? He would, of course, travel by whichever line would carry him cheapest, and if there were only one line, the question of his travelling or not would clearly be decided by him on grounds quite irrespective of the cost of the line In fact, it is clear that such an argument rests on the folly I have hinted at above, of regulating fares by the necessities of the few, rather than the convenience of the many.

II I proceed now to notice the second obstacle to traffic—the want of facilities for the convenience of passengers

Some of these have been lately commented on in a recent Government

* This has been computed on good authority in England to be 30 miles for 1*d* —what it may be in India I do not know

Resolution—they concern various minor points, all useful enough and important in their way, which need not be further adverted to here The chief obstacle of all under this head is undoubtedly *the trouble of procuring the ticket* Any one who has seen the pushing and struggling that take place at the ticket office of any large Railway Station in India before the starting of a train, will perfectly understand why no native, as a rule, will travel any oftener than he is obliged to do This point has been over and over again pointed out—the remedy for it is sufficiently obvious to every sensible man Yet it is not applied Why? The only possible answer is, that the English mind is essentially apt to run in a groove—if you like, on a rail—and that it is very difficult to get it out of the one or oft the other Suppose the strictly parallel case that has been often adduced—that you could only buy postage stamps, to put on your letters, just before the mail went out, and at one inconvenient little pigeon hole amongst a pushing, struggling, crowd And, as the cases are absolutely analagous, so the remedy for one is clearly the remedy for the other Let ticket offices be multiplied—let them exist at every post office—or treasury—or respectable Bunyah's shop if you will—and let them be bought a week, or a month, or a year beforehand, if you like In the United States, there is a ticket office in the hall of every large hotel, besides other offices in various parts of every large town, where you can buy tickets for any journey you want to make, at any time, over any line

And here again, in the case at least of the Indian State Railways, we have special facilities for carrying the postage stamp analogy still further, by making railway tickets altogether general—one step towards which has already been taken by adopting the distance between two stations as a unit—an obvious improvement over a mileage rate Why then should not railway tickets of different colors represent fixed sums for so many miles or station distances—to be travelled by the purchasers at any time over any line in the country? and which could be bought like stamps at any post office? The only objection I have heard made is, that they might be forged—to which the natural reply is so might stamps and currency notes The fact is that the convenience of the arrangement would be so great, and its advantages over the present system so immense, that the ordinary Railway mind, accustomed to pigeon holes, stamping little checks, dispensing change, and to the general discomfort, squabbling and confusion of the present method, simply cannot take it in, and refuses to

believe that there is nothing in the nature of things to prevent a passenger stepping as quietly into his carriage, as a letter sliding into a letter box

If there is anything worse than the passenger ticket arrangements, it is assuredly that for the luggage A native clerk with an imperfect knowledge of English, produces a huge book, in which, after an abstruse arithmetical calculation, he slowly writes down an amount of information about the passenger and his traps, which is of no conceivable use to any one under the sun

On American lines, if luggage is paid for at all, it is charged *by the piece*—a numbered label is strapped on to each piece, a duplicate handed to the owner and the transaction ends But would you charge for a sea chest the same price as for a hand bag? the answer to which is, that people don't travel about with sea chests, and if they do, they would have to be left behind In this, as in all similar cases, rules should be framed to suit the average traveller with an average amount of common sense—not with a view of including all possible exceptions, and of incommoding ninety-nine passengers to avoid being cheated by the hundredth

It cannot be too strongly pointed out that a Railway, if it is to be made to pay, should be looked upon as a *shop*, and conducted on the principle of *attracting customers* If I want to make a profit by my wares, I do all I can to advertize my goods, and to entice people to buy (*even when they have no idea of buying*) by civility and even blandishments Does an Indian Railway present this aspect, especially to a third class passenger? I trow not From the moment he enters its precincts, he is virtually a prisoner and a slave, while if he has any idea of employing the line to carry goods for him, he is frightened by the perusal of a string of bye-laws apparently drawn up* to screen the Railway Company from any responsibility in the matter, and of impressing him with the idea that he ought to be very much obliged to the Railway for condescending to carry him or his goods at all

It is obvious that such a system is altogether wrong—every pains should be taken to attract travellers by low fares, comfortable carriages, convenient stations, suitable means of refreshment, and civility and protection from imposition. It is not enough, if the people won't travel in sufficient

* Suppose you were met at the entrance of a shop by the Proprietor who told you "Sir! I warn you before you enter my shop, that I will not be responsible, if any of the goods are damaged—or if *your pockets are picked—or if any mistake is made in giving you change*—or if you are subject to any other inconvenience, loss or damage Yet this is very much the principle on which Railways act with regard to their customers.

numbers, to sit down contented and say, it is their own fault It should be ascertained *why* they won't travel, and additional inducements should be offered So in the case of goods—if the Railway wants to carry goods, it should *tout* for them—smooth all difficulties in the way of reception and delivery, and if they won't come to the Railway from a distant town, *go to that town and fetch them*

With regard to the above item of "comfortable carriages," it is strange that the greater convenience of the American cars, especially in such a climate as this and for long journeys, has not yet been recognized They possess greater facilities for ventilating and cooling, they enable the passengers to move about at will from carriage to carriage while the train is in motion, and by enabling the conductor or guard to pass from end to end of the train, they facilitate the taking of tickets, the giving of information to passengers, and that general supervision which is important in the case of native passengers, and which can now not be exercised, except when the train is at rest They also enable conveniences to be provided for the supply of natural wants and bodily refreshment in a manner which is now only accomplished by undue detention at stations

To sum up what has been above argued—it is suggested that, in order to develope the Railway traffic in this country properly, and so as to make Railways pay—it is necessary—

1st To reduce third class passenger fares—looking upon a rate of two pies per mile as a *maximum*, and which, following the experience of the most successful English lines, should be reduced to one pie

2nd To facilitate the comfort and convenience of travellers (*a*) By multiplying the number of ticket offices, and making tickets procurable as easily as postage stamps (*b*) By charging for luggage by the piece, and doing away with all booking and weighing (*c*) By adopting the American form of carriage, by which greater comfort and convenience will be enjoyed by the passenger, and delays will be obviated at stations other than what is necessary for taking up and setting down (*d*) By establishing Booking Offices at all towns within reach of the line, where delivery can be taken of goods to be conveyed, instead of waiting for the goods to come to the rail (*e*) By impressing on all Railway employés, from the highest to the lowest, that it is *their* fault if the people don't travel!

I invite discussion on all these points

J G. M

No CLXXXIII

PROTECTION OF PIERS OF LARGE BRIDGES ON THE SCINDE, PUNJAB AND DELHI RAILWAY.

[*Vide* Plates V, VI, VII VIII and IX]

The three important bridges on the Scinde, Punjab and Delhi Railway are those over the Jumna, Sutlej, and Beas Rivers They are all of the same type, being formed of double triangulated girders in 100-feet spans in the clear, the railway passing above the girders, which are supported on single cylindrical piers 12 feet 6 inches in external diameter, and sunk to an average depth of 40 feet below low-water level

The Jumna	bridge	consists of	24	such spans
,, Sutlej	,,	,,	59	,,
,, Beas	,,	,,	31	,,

The Railway was opened for traffic throughout in the year 1870

During the floods of 1871, the fall of several of the piers which had been exposed to severe scour rendered it necessary to take precautionary measures to arrest further destruction of these cylinders

The method adopted has been that of depositing masses of loose stone, blocks of brickwork, or kunkur, round the piers, and this plan has so far been attended with satisfactory results

The comparative sections of the Sutlej, taken before and after the deposition of stone, show that the tendency of the stone protection is to deflect the scour from the vicinity of the piers, whereas, previously, the tendency of the current was to hug the piers and undermine them At the west abutment of the Beas, it has been found that the stone thrown in to protect the long splayed wing-walls, after having been exposed to a very severe rush of water, took a slope of from $1\frac{1}{2}$ to 2 to 1 after the first floods, and has not since moved.

ELHI RAILWAY

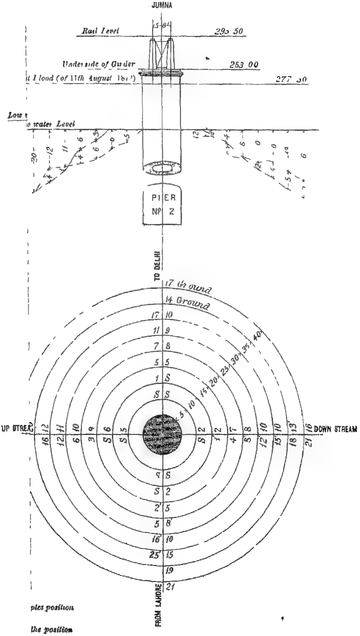
NOTE

Position of Stone befo e Floods shown thus

, after ,

Bed of ' Sutlej before deposit of Stone

8



ples position

the position

The accompanying sections (*Plates* V and VI) give a fair sample of the form which the stone placed round piers has assumed, after being subject to heavy scour in the main channels The quantity of stone placed round each pier has varied much, as many of the piers have not been exposed to the most severe scour that may at some future time come upon them with variations in the channels of these rivers, but it is estimated that an average of 20,000 feet of stone per pier will suffice A large supply of stone is kept in reserve at each bridge, and the piers will require constant attention and watchfulness for many years to come It will be observed that, in some of the latter sections, the stone is higher than in the earlier sections, this is accounted for by additions of stone made from time to time

During the floods, soundings are taken three times a day at the piers exposed to scour, and any settlement below 12 feet from high-flood level is at once made up to that depth by throwing in stone

A somewhat unaccountable case has been observed at the Sutlej Bridge in pier No 53, which sank two inches after the silting up of the channel, at a time when there was no water at the surface A similar case has been observed at the Markunda Bridge in one of the piers, which sank two inches shortly after the opening for traffic, and, though it is protected by 5,000 cubic feet of stone and sand for 40 feet of its depth, it has since settled three inches more

Jumna Bridge —The accompanying plan (*Plate* VII) shows the several features of the Jumna Bridge and its protective works

During the floods, the land for a considerable distance beyond the banks of the river, is covered with water, which, when the floods subside, flows parallel to the embankments, and, to avoid the damage which would otherwise ensue, the embankments are protected for a considerable distance with stone, trenched in to low-water level, about 10 feet wide, and up the slope, to above high-water level Groynes have been thrown out to keep the river to its course They are composed of earth and sand faced with stone and sloped towards the river In 1872 they had a very heavy body of water against them, the hearting was washed out in some places causing them to settle, but the settlement was made good with stone Each season the settlement has been less, and, although during last season, the scour was as deep as 28 feet on the face, and 37 feet near the nose of the groyne, no permanent injury was done

The material used for the protection of the piers was block kunkur,

obtained from quarries about 5 miles north of Sirsawa Station. The earth and foreign substances in the interstices of the kunkur were found to wash out and fill in the spaces between the blocks, so that it became a solid mass only to be removed by crow-bars.

The quantity of stone used round the piers varies from 37,000 to 2,600 cubic feet. The average round each pier is about 15,600 feet. The total quantity deposited is as follows :—

Round 23 piers,		358,660
East abutment and berm,		450,000
West ditto,		220,500
Toe of east bank,		49,000
" west "		74,000
Main bund,		1,059,525
Lower "		325,000
	Total,	2,536,685

Sutlej Bridge.—The principal features of the Sutlej bridge and its protective works, are shown in the accompanying plan (*Plate* VIII.)

The effective waterway of the bridge is from pier 1 to pier 49. The remaining spans are closed with a bank faced with stone rising two feet above highest flood level; from 49 to 50 for two seasons a powerful current has set against this bank, which however has not been affected by it. The water, after meeting the obstacle, flowed along its face, and then swirled round the end with great velocity through spans 46 and 47, causing a scour to the depth of about 40 feet between the piers, but in no way affecting the stone round the piers, beyond causing settlement. As the floods subsided, the space scoured out silted up, and a flooring of loose stone was laid on the silt between the piers.

The two small irregular bunds (marked 1 and 2 on plan) were originally formed of earthwork and brushwood by the contractors, but were subsequently repaired and faced with stone by the Company. The long upper bund has also been faced with stone, and extended about 600 feet into the river, the end being sloped out and formed entirely of stone. The effect of the latter has been to throw the channel further over, and to relieve the strong rush along the stone revetment from pier 49 to 53, and, gradually, to silt up the bay below the nose of the spur.

Piers 1 to 49 have had stone deposited around them, varying in quantity from 43,500 to 8,200 cubic feet. The quantity of scour around these

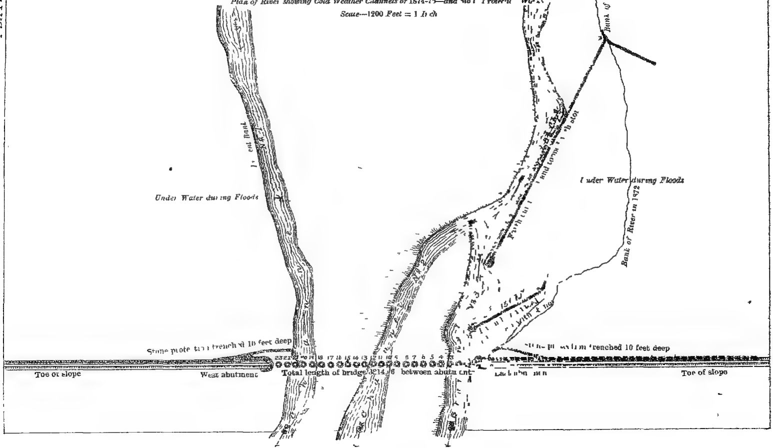
PLATE II.

PROTECTION OF PIERS OF LARGE BRIDGES ON THE SCINDE PUNJAB AND DELHI RAILWAY

JUMNA BRIDGE

Plan of River showing Cold Weather Channels of 1874-75—and Stone Protecting Works

Scale—1200 Feet = 1 Inch

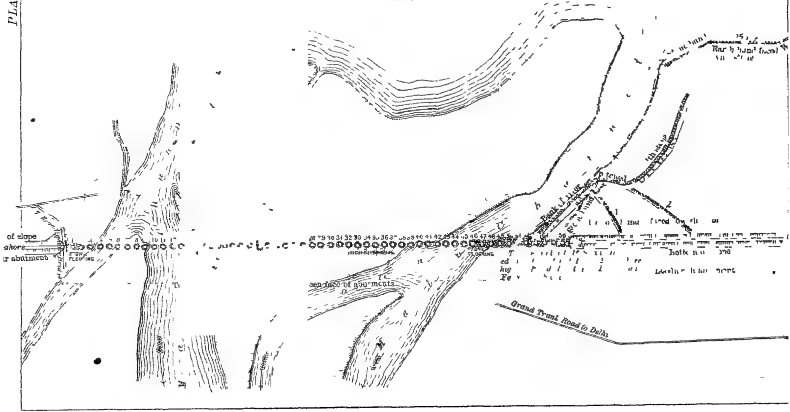


PROTECTION OF PIERS OF LARGE BRIDGES ON THE SCINDE PUNJAB AND DELHI RAILWAY

BEAS BRIDGE

Plan or River showing Cold Weather Channels of 1874 75—and Stone Protection Works

Scale—1200 Feet = 1 Inch



PROTECTION OF PIERS OF LARGE BRIDGES ON THE SCINDE PUNJAB AND DELHI RAILWAY

BEAS BRIDGE.

Plan of River showing Cold Weather Channels of 1874-75—and Stone Protection Works

Scale—1200 Feet = 1 Inch.

piers averages 16,774 cubic feet The total quantity of stone deposited is as follows —

At the piers 1 to 49, ..	826,9[illegible]3
Flooring and other protection,	274,940
Phillour abutment,	83,983
Protecting bunds,	1,218,719
Total,	2,401,595

Beas Bridge —The accompanying plan (*Plate* IX) shows the general features of the Beas Bridge and its protective works The west bank of the river is high ground, but on the east bank the water spreads itself in floods The two end spans 1 and 2 and 33 and 34 are floored with loose stone, and, from this latter flooring, springs the east abutment, from which runs a long bund 4,500 feet in length, which was constructed by digging a trench 20 feet wide and 10 feet deep The earth was thrown back to high flood level and then faced and topped with stone, the toe of the slope towards the river face being composed wholly of stone At A is a depression or causeway to allow the flood water to drain off when the floods subside The land end is well trenched with solid stone, and the small cross bund connects the main bund with the embankment as an additional protection to the abutment

The stone round each pier varies from 30,366 to 1,240 cubic feet The quantity of stone round the 33 piers averages 13,248 cubic feet The total quantity deposited is as follows —

Round the piers,	472,773
East abutment,	141,387
West, "	201,900
Bunds,	700,771
Total,	1,516,831

No. CLXXXIV

THE USE OF CONCRETE IN INDIA

By Fitzhugh Cox, Esq., *Assist. Engineer, P. W. Department*

Sialkot, November 1875

The use of concrete to any extent in this country is very recent, and though this material is being daily more widely applied, it must be admitted that the use of concrete in India is yet in its infancy.

At present it is not much used beyond the requirements of bridge and building foundation, and there is an evident distrust and dislike shown to its application, as the only material for bridges, roofs, walls of buildings, cylinders of wells, and in fact to anything where stone masonry or brick-work has been hitherto exclusively used. The argument usually adduced against the more extended use of concrete work is the difficulty in this country of securing the strict supervision which must be exercised over monolithic works, to ensure that the native agency employed mix the materials in the proportions ordered—that they ram the material equally—that they do not put too much water—and that they keep it thoroughly wet for some time after the completion of the work. There are other difficulties too in the way of establishment, &c., as often a District Engineer has to perform a small piece of work of this description only once now and then, and finds it easier to ensure good work by estimating for brickwork, than running the chance of failure with an untried, or not thoroughly competent, superintendent on the spot.

In this short Article, I do not pretend to show all that has been, or may be done, but I would raise a voice in favor of the use of this most useful material in a more extended form than hitherto. My experience in this mode of building is not sufficient to constitute me a special authority on

the subject, but such experience as I have had, may entitle my opinion to some weight in regard to the use of concrete in the localities (in the Punjab) in which I have been employed, and my object will be served if I can draw increased attention to this material, and can influence others to devote their energies to developing this most useful form of construction, which is eminently adapted to a country where stone is scarce and expensive

Materials.—The first thing to be considered is the material In the Plains the most abundant material as a rule is broken brick, kunkur lime, or stone lime and súrkí

For moderate sized works, there is generally a sufficiency of the former material available, but in new work, where a large amount of concrete has to be laid down as foundations, the 'broken brick' will have to be expressly made

Stone.—This material if it can be obtained is superior to brick for concrete purposes, but it is not often that it is procurable at reasonable rates, and broken stone again requires to be broken *quarry*-stone with sharp rectangular edges, and not merely broken *pebbles*, such as those found in the lower hill ranges the stone should be any hard sort procurable, care being taken that the soft grey sandstone which is very common is not mixed with it.

Brick.—Next in order of quality is broken brick, or more properly ballast, as the *moulded* brick is superior to the *broken* brick properly so called Moulding brick ballast is extremely simple It consists merely of spreading slabs of well tempered mud over a sanded floor, the slabs are smoothed down by hand with a little water to the required thickness one inch, and when somewhat dry, cut with a knife into one inch squares By merely running a spade under them, the ballast is broken up, and ready for burning in oopla kilns

Kunkur.—Next in order come kunkur nodules If block kunkur of a hard blue kind is procurable, it would rank before broken brick, but the ordinary kunkur as a rule is not always reliable, and has other objections In the first place it is more expensive, it has to be washed, the whole of the mud is not easily cleaned off, it catches mud and dust more easily than broken brick, and lastly, it is more easily broken in ramming

The size of the aggregate, (as it is called,) should be cubes which will pass through a one-and-a-half inch ring for thick work, and through a

one inch ring for fine work Some Engineers prefer to use smaller aggregates, and others larger, the latter is the lesser mistake of the two, as far as strength goes, but it uses more of the expensive material, viz, mortar After a good many trials, I have come to the conclusion that the above sizes are the most suited

The amount of mortar required should be just such an amount as will fill the spaces between each piece and *no more* as this in practice is rather difficult, it is usual to add from five to ten per cent excess The voids in the ballast can easily be ascertained, by filling a (cubic foot) box with well saturated ballast, and then pouring in water from a measured vessel, or by shaking sand into a similar box filled with dry ballast The smaller the size of the aggregate, the smaller will be the quantity of the mortar used, for the above sizes, I have found 35 to 45 cubic feet of mortar (dry) to be sufficient, but I have heard of as much as 50 to 60 cubic feet per cent being used, my experience tends to show that this is a mistake and a waste of material Gillmore in his work on "Limes, Hydraulic Cements and Mortars," Chapter VII, para 440, says—"As lime or cement is the cementing substance in mortar, so mortar itself occupies a similar relation to concrete or bèton Its proportion should be determined in accordance with the principle, that the volume of the cementing substance should always be somewhat in excess of the volume of voids in the coarse materials to be united. The excess is added as a precaution against imperfect manipulation"

As this is more necessary in India, a rather larger percentage is allowed, and the proportions should therefore be regulated by the following —

1st By the size to which the aggregate is broken, determined by actual experiment.

2nd By the amount of skilled supervision which can be given to the work

Composition of Mortar—The mortar may be composed of lime, either fat or slightly hydraulic, kunkur lime or kunkur cements With fat lime, some sort of puzzolana must be used, and good coarse sand may or may not be used at discretion of Engineer The puzzolana in common is surkí, and* a good deal of diversity of opinion on the subject, viz, whether thoroughly burnt bricks and refuse, or whether underburnt brick &c, should be converted into puzzolana As a rule, I believe the thor-

* *Vide* Article No CLXXI., by Mr Dejoux on the subject

oughly burnt brick advocates carry the day, one reason being, that it is very difficult to point out to a native workman the particular amount of 'underdoneness' allowed, and still more to make him stick to that sort, as the more easily a brick is broken, the more he can do in a day, and, therefore, he chooses the softest possible

Pucka súrki then being used, should be of such a size as to pass readily through a No 8 wire gauze screen

Lime Slaking —The lime should be brought to works unslaked, and to fit it for use, it must be slaked Now to this subject of slaking very little attention is paid as a rule. There are three methods which Gillmore in his treatise above alluded to treats so fully, that to those who wish to study the subject more in detail, I would recommend them to read Chapter VI, paras 317-341 I will merely here endeavour to show the best and easiest away, and wherein lies the defect of the usual native method

The best way to slake lime is to lay it out on a platform of bricks in a layer not more than six inches in depth, and surrounded by a raised side of bricks backed with earth forming a shallow basin On this should be poured *at once* the quantity of water necessary to slake the mass, which will vary from $2\frac{1}{2}$ to 3 times the volume of the quick lime After which it should be left undisturbed until required for use, which should be not before the end of the third day from that on which the lime was slaked If it can be covered for that time so much the better.

Most slaked lime will be found (unless slaked as above) to be full of small lumps about the size of a pea, or even larger, the reason of this is, the lime during slaking has been suddenly chilled, the bheestie brings a skin full of water, (perhaps not a tenth part of what is necessary for the amount of lime spread out,) he throws this on, and then goes leisurely away to bring more, taking perhaps ten minutes to bring another, he arrives just as the lime is beginning to expand, and then he throws on in like manner the second skin-full, as a rule he puts too little even when the operation is completed, and this is a constant source of expansion in work and cracking in plaster, besides having a good deal of the useful energy of the granulated lime literally thrown away as the puzzolana (súrki) cannot amalgamate so readily with the granular lime, as it will with the powdered lime

The fat limes can be used as a general rule with proportion of 1 part to 2 parts of súrki, well mixed in a dry state

Slightly hydraulic limes do not take so much water to slake, neither should they be used so long after slaking, as a general rule, the more hydraulic a lime, the sooner it should be used Súrki too can only be used in a lesser proportion, varying with the amount of impurities which they contain, and which vary from 10 to 20 of the whole

Kunkur lime or kunkur cement, I consider the latter the proper term for this material, or at any rate for such as contains anything between 45 and 55 per cent carbonate of lime

Mr Neilly, in a paper in one of the former numbers of the Roorkee Professional Papers, dated 17th October, 1872, para 18, says, "The true appellation of cements is claimed for many of the burnt kunkurs" an opinion in which I fully concur, and in fact consider that as a general rule, kunkur lime should not only be *considered* a cement, but *treated* as such

I may note *en passant* that the method of burning which I found most satisfactory was to burn kunkur cement in open clamps with charcoal. I never heard of its introduction any where else until I had it in use for about one year I first laid a layer of oopla on the ground, kept in by a ring of bricks with three or four fire holes running from the centre outwards, in order to start the fire evenly The charcoal being first measured in boxes, was laid on the heaps of kunkur (broken small) in the proportion of 40 feet of charcoal to 100 cubic feet of kunkur, or about 10 maunds of the former The kunkur and charcoal were then shovelled into baskets, which were emptied on to the oopla with a rotary motion, spreading the kunkur evenly and mixing it most effectually, this went on until a conical heap was formed containing about 2,000 cubic feet of kunkur, the most useful size The outside had then a course of bricks laid on, and was carefully plastered over The kiln was lighted from the bottom, and allowed to burn itself out Should the fire break out in one spot too fiercely, it was easily damped down with fresh mud The outturns were found very satisfactory on the whole, and with less overburnt kunkur and cinder than in the common V-shaped kilns

The kunkur cement should be pounded so as to pass through No 8 wire gauze mesh It should be mixed only a little while before use, and used with as little water as possible

In mixing the aggregate with the matrix or mortar the best way is to mix the fat lime and surkí together, first dry, and then to lay it on the aggregate, which has been previously wetted in the proper propor-

tions, the aggregate below in a layer not more than 4½ inches thick, then the matrix, then another layer of aggregate, and then the matrix. The whole should then be slightly wetted by means of a watering pot and thoroughly turned over. I found two men digging with forks working backwards and forwards and two turning over from right to left, sufficient to mix the whole well, the material being watered the whole time—by this means, a proper supply of water in finely divided streams was supplied to the mortar, and with proper attention no difficulty was experienced after the men had become accustomed to the work. The operation is one however which requires constant skilled supervision, as though the matter is an apparently easy one, it is not so in actual practice. Gillmore quoting from a report by Lieut. Wright on the Fortifications of Boston Harbour says, para. 450, "The success of the operation depends entirely upon the proper management of the hoe and shovel, and though this may be easily learned by the laborer, yet he seldom acquires it without the particular attention of the overseer."

I tried a machine for mixing, which was a much slower and more expensive process, and the results were, if anything, rather worse than hand labor, as all the aggregates fell or rolled to the sides of the heaps, while the mortar remained in the middle. This machine was an upright box about 12 feet in height and 3 feet square in section, containing shelves at an oblique angle, the material on being thrown in was dropped from one shelf to another until it reached the base, where it found an exit at a small door. The object was to thoroughly incorporate the aggregate in the matrix, but as before said, the results were not satisfactory.

Ramming Concrete.—The material when mixed should be carried away, and carefully placed in the trenches or boxes in which it must be rammed, *first* at the sides, and *then in the middle*, until it is firm and compact. If too much water has been poured on, the whole mass becomes a shaking jelly, the tendency of which is to drop the heavier particles to the bottom, the lime and finer portions of súrki rising to the top. If after a slight ramming this is found to be the case, the only remedy is to cease ramming, allow the water to settle for half an hour or so, and then to take up the material and relay it. The test of the proper quantity of water, is to take a small quantity of concrete in the hand, and after giving it a moderate squeeze with the thumb and finger, it should easily fall in a cake, leaving scarcely a soil on the finger. Too small a quantity of water can

easily be remedied by merely watering the material after each ramming, which should bring the water again to the surface the next time in the form of dew-like drops

Between each successive ramming, the face should be picked up with a sharp pick, otherwise the lime will form a thin film between each course, and effectually prevent any adhesion between the two

Sand.—In my experience I have found that as a rule sand is not available, at least sand of such a quality as to make it a desirable ingredient in mortar where it can be obtained it is a very desirable one, and should be used in equal proportions with *súrki* It should be clean, sharp, coarse grained sand and free from mica

It is not easy in an Article of this description, to fix the proportions for mortar, viz, for the lime, *súrki*, or sand, as that depends entirely on the quality of the former, and these proportions must be different in different localities with their varying qualities and sorts of materials

A great addition to the strength of the concrete is made by mixing about 20 per cent of fine aggregates with the coarse, they may be cleaned road scrapings consisting of washed kunkur, or of coarse surki screenings or fine gravel, these help to fill the voids and do not leave such a number to be filled by the mortar

Concrete should be kept damp as long as possible, especially in such a climate as India, for two months in the hot weather, and should when new be protected from the frost

The former part of this Article has treated generally of concrete, and more particularly as applicable to course work, such as foundations, where the only points of attention worth special care are, the thorough incorporation of the materials, and the proper ramming of the whole, so as to insure a solid, compact, and non-porous mass But concrete is applicable to every use to which brickwork can be applied, and I will now endeavour to show some of these uses, to which it can be in India applied

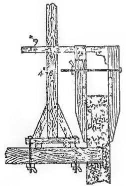
In the year 1830, an architect, M Lebrun, built himself a house on his estate at Alby (Department du Yarn) entirely of béton The béton was composed of one part hydraulic lime, one part clean sand, and two parts shingle, averaging one inch in size The faces of the walls were plastered with sifted sand and mortar The building appears to have been most successful, and its cost was about one-half what it would have been had it been built of brickwork

The term *béton* is often restricted to concrete whose matrix is hydraulic lime or cement, whereas *concrete* is the term applied to a composition of fat lime and puzzolana. The words concrete and béton, although originally by no means synonymous, have become almost so by use, concrete being the term most used, whereas the matrix in Europe is more generally hydraulic lime or cement, than common lime.

In the construction of buildings, there are two methods in use—*1st*, the monolithic, and *2nd*, the block system.

Monolithic concrete.—The monolithic, provided sufficient skilled supervision has been given to the building, during its construction, makes the more solid erection, but the block system has this advantage, that by reason of the small size comparatively of each block, all danger on account of bad workmanship is put out of the question, even though a bad block may go in now and then, those above, below, and around it protect that portion from collapse, whilst it at the same time offers additional facilities for the prevention of the introduction of bad work into the erection. It allows of a greater variety of detail of ornament, and avoids any unsightly bulge in the wall due to the defect in setting up any particular box, or case.

In the monolithic method, the concrete is placed in boxes formed of stout boards, and of any convenient length, tied together by horizontal irons above or below, the latter are pierced with holes both to suit alteration in width of wall, and also to assist their extraction on removal of the case when one set have been filled and consolidated.



In the margin there is a sketch showing a device by Mr. E. E. Clarke, for the erection of monolithic concrete houses. The following is Gillmore's description of its use :—"It consists essentially of a wooden clamp, the vertical parallel arms of which can readily be adjusted by means of traverse screws to any required thickness of wall.

"These arms support the planking which determine the thickness of the wall, and are attached—one fixed and one movable—to a horizontal brace. When in use, the entire apparatus is kept in position by securing this brace to some fixed point of

support In carrying up the walls of a building, these points of support are provided on the inside, being vertical posts secured to the ground, in the first instance by braces, and afterward to the flooring joists of the upper stories "

The arches over doors, windows and other small openings, may be rammed up solid in horizontal layers, greater pains being taken to make them thoroughly homogeneous, but the arches of the larger openings, such as verandah arches, should be rammed in 6″ or 8″ courses, radiating towards the centre, unless their thickness is considerable, it is better to build the arches of blocks thoroughly hardened, which have been made to suit the radius, &c, required

The roof—The roof may be made of a very light semi-circular half arch with a few tie-rods for the verandah roofs, and a semi-cylindrical roof for the main rooms The roof should be beton of very fine material, carefully consolidated, and when about half dry, rendered with Portland cement and kunkur cement in the proportions of 1 to 2, to close up any hair cracks which might have shown themselves, and also to prevent as far as possible the growth of vegetable matter, and to facilitate the passing off of water during rain With this exception, the whole of such a building might be made of concrete, at a cost of not more than two-thirds the amount a similar construction of brick would cost It is hardly necessary to say that all the arching centres must be of timber.

Concrete Blocks—In the block system, the building is constructed of blocks carefully rammed in boxes or nests of boxes containing four to twelve blocks each The material is of two sorts, fine and coarse, a small quantity of fine being laid on the side to form the outer face of the block, the body is made up of coarse, the whole being rammed together The cases had better be left on for one day and removed the next, and allowed to dry in the air under shade for a week, when they should be placed in a tank of water to indurate for six weeks to two months, at the end of that time, they may be taken out and dried under cover

In this way cornice bricks, moulding bricks, and patterns may be moulded with good sharp edges, and not only so, but the tints can be varied by dusting the nearly dry outer surface with red brick dust, grey kunkur cement, black vitrified brick dust, or any other coloring material obtainable This would greatly enhance the appearance of a building in which color formed a part of the design.

The blocks for ordinary building purposes should be in any sizes, suitable to the construction required. Common blocks should be in the proportion of half breadth to length and one-third thickness. For instance, if it were proposed to build an 18-inch wall of block concrete, they might be 18 inches long 9 inches wide and 6 inches thick, or 3 feet long 18 inches wide and 9 to 12 inches thick: the former would be the more useful size for a height of over 5 feet, as the latter would require tackle to put them in position, whilst the former might be done by hand labor.

Such blocks might be made with a sunk joint $\frac{3}{10}$-inch depth, this would add greatly to the ornamental appearance of a building, and cost nothing beyond the nominal first cost of the mould.

Plain work, such as is usually put into Government buildings, could be done in concrete for the same cost as kucha pucka brickwork, (viz., burnt bricks in mud mortar,) with pointing on the external face: nay more,—in works where a good deal of brickwork is going on, and where the moulds required would be used for several buildings, and where a suitable aggregate can be obtained at a moderate cost,—I consider that concrete could satisfactorily compete with that cheap, but not too good, substitute for pucka brickwork. With block concrete, hollow walls could be easily constructed, each block having either a hollow in its centre, or a nick cut out of the ends, similar to the hollow brick system.

Block concrete would form a very neat addition to a building, as round windows, and doors, or at the cornices of buildings, and with any light colored mortar, it would have the appearance of bath stone dressings. When placed under woodwork and over burnt brick and mud mortar masonry, it serves the two-fold purpose of wall plates and protection from white ants.

The principal drawbacks to the use of block concrete is the *system* of the P. W. Department: buildings have to be built in a very short time, and proper time cannot be given in their manufacture before the time they are required for use: as often sanctioned buildings are not put in hand until but a short period before the end of official year, and block concrete requires not only careful supervision, but also time to season the blocks. The best season is during the rains, as then they get a gradual drying, and also get fairly hard before the cold weather and frost.

Flooring.—If concrete were made of Portland cement, and over-burnt brick broken to the size of a pea, I believe it would form a very excel-

lent and lasting flooring, easily laid, and not likely to get out of order. A pavement was made for the footway of King William Street City, of Portland cement and oolitic limestone, which lasted 14 years, and this is certainly longer than the life of a brick in an Indian Barrack Room.

Wells could be made of monolithic, or block concrete, at a less cost than brickwork; in the former case, a wrought-iron cylindrical case about 15 inches deep would be necessary, but for a small work a wooden one might be made to do duty, and a saving could be affected by diminishing the thickness of the cylinder, as in deep wells 9 inches would be ample for the first 20 feet, $1\frac{1}{2}$ feet for the next 30 or 50. In wells 6 to 9 feet diameter, blocks might be made so as to divide the circumference into 6 to 10 parts, and would then be easily handled and laid.

Tanks.—Concrete is a very useful material in the construction of tanks, as it is quite impervious to water, *i.e.*, if properly made, and has no joints through which the water in brickwork so frequently finds its way.

For district bridges, Irish bridges, mile posts, (to this latter use it is largely applied in the Irrigation Department,) encamping ground boundary pillars, and such like work, it is especially adapted.

It has been largely used on the Northern (State) Railway bridges to throw in round the piers, and appears to have well answered its purpose. A very fair road might be made over some of the Indian rivers (narrow) in which quick sands abound, by throwing in blocks of concrete until a firm base is attained, over which the permanent road could be made.

The above are some of the uses to which it could be, or has been, applied, and I will in conclusion sum up the special points of attention to ensure good work and workmanlike finish, combined with a fairly low cost.

1st. The aggregate should be a medium size, not smaller than $\frac{3}{4}$-inch cubes, nor larger than $1\frac{1}{4}$-inch cubes; it should be hard, not too porous, nor yet perfectly impermeable by water; it should not be round pebbles, and should be fairly wet before mixing with the water, otherwise it too rapidly absorbs the moisture of the latter, much to the detriment of the whole.

2nd. The lime should, if fat, be thoroughly slaked, and laid with a sufficiency of water, which should be added at once not in driblets.

3rd. The súrkí should be not less than fairly well burnt pounded brick. The sand should be large, coarse, clean, and free from mica, or at least tolerably so.

4th The lime and surkí should be both *finely* sifted and thoroughly incorporated with one another, this being one of the great secrets of good mortar, after having been once made and set, mortar should not be made over again, therefore only one day's work should be made up at a time The mortar should not be too wet, and it should be thoroughly turned over until the aggregate is well incorporated with it

5th The concrete should be carefully *laid* in the trenches or boxes in which it will be rammed in layers not exceeding 6 inches, not allowed slowly to roll out of a basket, or to be thrown from a height of a foot

6th In ramming, the sides and corners should first be consolidated, and then the centre, and watered now and then, as the water contained in it becomes absorbed by the sun or earth The ramming should all be done in one operation, and it should not be re-rammed after a considerable interval, or else the "set" of the mortar is spoiled After every course the surface to be scraped and scratched, so as to present a rough face to the succeeding course

7th Concrete should be kept damp and allowed to season as long as possible before being used, or before any great weight is applied It should be protected from the sun and frost

8th Block concrete should not be subject to blows or shakes when fresh, and all concrete should be clean without any mixture of vegetable matter, such as straw, grass, &c

9th In conclusion, concrete can be used in almost any position, and for almost every kind of work to which brickwork is applicable, at about half to four-fifths the cost of brickwork But it requires better supervision than brickwork, and thorough attention to details

F C

P S—Since the foregoing went to Press, I see that "The Building News" advertises a Prize Competition for a Concrete Villa, [*vide* Building News of the 12th November, 1875] In the Notices of "Contracts open," there are constant notices of concrete erections of various kinds, showing that the subject is attracting, as it ought to do, a daily increasing interest,—

No CLXXXV

STONEY'S PATENT IMPROVED SURKI SCREEN

[*Vide* Plate X]

BY E W STONEY, ESQ, M I C E

THIS súrkí screen consists of a supporting frame-work of timber of the form shown in *Figs* 1, 2, 3, or any other suitable form, which frame may, for convenience, be supported by wheels to allow of the screen being shifted from place to place as required

From this frame a screen W (formed of suitable materials) is suspended by wires or chains A_1, A_2, A_3, A_4 placed wider apart at top where attached to the frame, than at bottom where they are fixed to the screen W, the screen is so suspended as to slope longitudinally towards the end to which the spout S for discharging the screenings is secured

At the middle of the screen W, and across its top, is placed a bar D, and in this, at its centre, is an iron socket in which the crank G, driven by the bevel wheels E, F, works

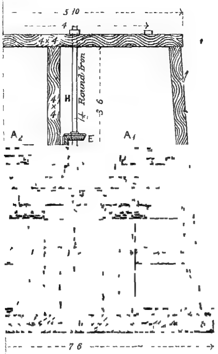
The crank G, with its shaft H, receives rotatory motion by turning the handle K, and thus causes the screen W to oscillate in every direction, as shown in *Figs* 1, 2, 3 and 4 *Fig* 5 shows four positions of the crank G, and the corresponding ones of the screen

The sloping suspending rods A_1, A_2, A_3, A_4 are attached by screwed eye-bolts to the frame, in order that their lengths may be adjusted so as to give the screen W its proper slope

The material to be screened is poured into the hopper X, which delivers it to the screen W

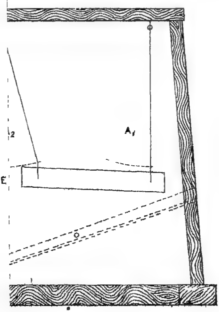
In consequence of the sloping position of the suspending rods A_1, A_2, A_3 A_4, *Fig* 3, the screen W is tilted alternately from side to side as the crank G rotates, *Fig* 2 shows its normal central position level,

Fig 2



END ELEVATION

Fig 4



while the blue lines in *Fig* 4 show it in the position corresponding with that of the crank G at 1, *Fig* 5, the right side being in this position raised and the left lowered, the black lines show it in its opposite position corresponding with the position of the crank at 2, *Fig* 5

It will be noticed that the rotatory motion of the crank G, combined with sloping suspenders A_1, A_2, A_3, A_4, causes the screen W to vibrate or oscillate in every direction, both horizontally and vertically, as shown in *Figs* 1, 2, 3, 4, 5, and so the material to be screened is most effectively shaken about in every direction, and uniformly distributed over the surface of the screen

The mode of using the screen is very simple the material to be screened is poured into the hopper X by women, or in any other convenient manner, while the handle K is turned continuously by manual labor, or motive power, if desired, the fine portions which pass through the screen are received on the floor below, while the screenings are discharged by the spout S into the spout V, the machine, if desired, may be fitted with a shoot O placed as shown by dotted lines on *Fig* 4, so arranged as to deliver the fine portions at the side

Both the fine portions and screenings can be removed at pleasure in any convenient way

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Work, Cost, &c, of Screen

A screen such as has been described 6′ 6″ × 3′ 6″, will sift 120 paras, or about 10 cubic yards of brick powder per day of eight hours, and the labor and cost was found at Madras to be as follows —

Labour and cost of Sifting

	RS	A	P
1 Man at four annas per day,	0	4	0
4 Women at one anna six pie per day,	0	6	0
Total cost of sifting 10 cubic yards,	0	10	0

equal to a cost of one anna per cubic yard for the entire quantity put over the screen 120 paras before sifting will give about 90 of fine powder, and 30 paras of screenings, but these quantities will vary according to the degree of fineness of grinding

A screen similar to that described and illustrated by *Figs* 1, 2, 3, costs, inclusive of Royalty, about Rs 100

All parts of these machines are so simple, that they may be made by

ordinary native smiths and carpenters, they are in use on the Madras Railway where they have been found so efficient, that the Deputy Consulting Engineer for Railways recommended them for use in the D P Works

They are easily worked by one man, and not liable to get out of order, so that it is hoped their many good qualities may recommend them to engineers engaged on large works in India

The author, having made numerous experiments on the manufacture of artificial hydraulic mortar and concrete, found that most excellent results could uniformly be obtained by mixing surki and sand with fat lime in proper proportions

These experiments clearly showed that in order to ensure success, it was necessary to have the surkí in a state of fine division, it having been found that the finer it could be ground and sifted, the more regular and energetic was its action

The results obtained when making these experiments impressed upon the Author the necessity and importance of having for his works a simple and easily worked machine to produce fine súrki, and lead him to work out the screen above described

The Chief Engineers of the Madras and South of India Railways, as well as the Consulting Engineer for Railways, Madras, have seen these screens in use and can testify to their efficiency

Col Drummond, R E, has also seen them working

The following is an extract from a report made by Capt Ross Thompson, R E, Deputy Consulting Engineer for Railways, Madras

"For sifting brick dust for the preparation of concrete for filling cylinders, Mr Stoney has had a very simple and efficient machine constructed in the temporary workshops at the Cheyair bridge site

"It imitates in a most perfect manner the action of a man's arms when giving motion to an ordinary hand sieve, and sifts large quantities of dust rapidly with a small expenditure of labor

"I am glad to find a good sized working model of this machine has been procured for the model room of the Civil Engineering College, as Public Works Officers would find it an extremely useful, cheap and efficient machine on large works"

All inquiries relative to them should be addressed to the Author, Madras Railway, Chief Engineer's Office, Madras

E W S.

17th May, 1875.

No CLXXXVI

'CENTRAL-LADDER-RAIL' MOUNTAIN RAILWAY

[*Vide* Plates XI, XII, XIII, XIV and XV]

Being translations from the German and French, with illustrations

BY CAPTAIN J L L MORANT, R E, *Assoc Inst C E, and F R G S*

THE following translations are offered to the readers of *Indian Engineering* in connection with Paper No CLXV, which appeared at page 244 of the IVth Volume All Foreign weights measures and money have been converted into their English equivalents

FIFTH ADMINISTRATION REPORT OF THE RIGI-RAILWAY COMPANY FOR THE YEAR 1874

(*From the German*)

[*Vide* Plate XI]

To the Shareholders of the Rigi Railway Company

GENTLEMEN,—The Managing Committee of the Rigi Railway Company has the honor to lay before you its Fifth Annual Report for 1874

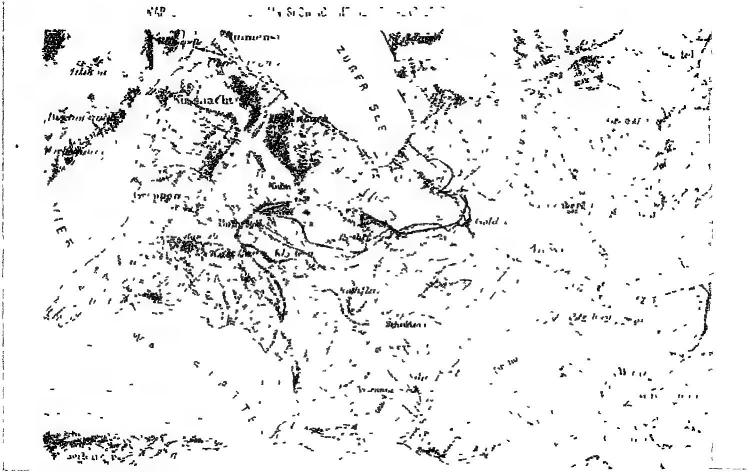
I Relations with the authorities of the Confederation and with those of the Cantons

In 1874, with the approval of the Consulting Engineers of the Swiss Railway Department, a contract was entered into for improving the Widenbach stream at Vitznau In 1870, 1873, and 1874, the Widenbach channel having become partly closed with fallen débris, the tunnel below the Schnurtobel river was much injured by the dammed up waters before they were able to escape into the Lake We have, therefore, determined to entirely reform the bed of the stream at our own expense, so that no injury can possibly occur to the adjoining works We have put this mat-

ter on a legal basis, and purpose carrying it out this autumn on a plan drawn up by Mr E Mohr, the Chief Engineer of the Canton This plan has met with the approval of the National Confederate Railway Department Lastly, we must notice in this our Annual Report, that the plans required by Article 18 of the Swiss Railway Law have been placed by us in the Archives of the Confederation These plans consist of a complete general plan of the position of our railway with longitudinal sections of the lines

II Our relations with other Railway undertakings

As the Arth-Kulm railway is to be opened for traffic next summer we made it known that we were prepared to make all necessary arrangements at the junctions with the Staffel-Kulm line, and at the Kulm Station These points were discussed with the Managing Committee of the Arth-Rigi Railway at several conferences, and were brought, as we hoped they would be, to a generally satisfactory conclusion The Arth-Rigi Railway Company is laying a second line of rails between Staffel and the Kulm Station, so that each Company will, on this second line being completed, possess a line for its own sole and special use The Proprietress has agreed to enlarge the grounds surrounding the Kulm Station, so that there will be sufficient room for our day-traffic station platform, and for our night sheds for five trains The station will thus serve for the administrative purposes of both railway lines, particular localities having been assigned to each Company for the delivery of tickets and of luggage Each Company is to select and pay its own ticket collector, but the other railway servants are to be chosen and paid for by both Companies in common The repairs to the Kulm Station are to be carried out by the Proprietress at our common expense Undue influence by the station authorities and by all the railway servants in directing persons and goods traffic is strictly prohibited at Kulm An agreement with the Regina Montium Company, which was in prospect last year relating to the leasing of the traffic of the Kaltbad-Sheideck Railway, was concluded in the current year on the terms mentioned in our last year's Report These are, that all our own expenses of every kind shall be paid back to us, and that we shall share in the nett profits over 5 per cent The sanction of the Swiss National Assembly has been obtained to this contract, as we mentioned before It was in force for only a part of the current year,


ZUGER SEE

because the Kaltbad and Scheideck line was not opened till July, and then only as far as Unterstatten, a distance of $2\frac{1}{4}$ miles A Committee for the construction of a railway from Lake Zurich to the Gotthard asked us on the 14th August, 1874, to take shares in their Company to the value of £10,000 They at the same time explained to us the proposed works and contracts, and their method of raising loans They subsequently communicated to us their Company's contract for the construction of a railway over the Brunig This embraced a branch over the Nase, alongside of the Lake of Lucerne, which would approach our Vitznau terminus We closely examined all these proposals, but found our Company's statutes did not admit of our sharing in such an undertaking to the extent requested For this reason we declined it Our relations with the United Lake of Lucerne Steamer Company, manifold though they were, were this year also of the most agreeable kind We gladly avail ourselves of this opportunity to acknowledge it

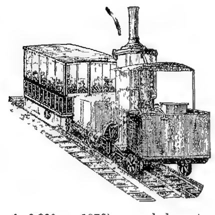
III *Traffic Management*

1 *General Account* —Trains began running on the 18th of May, and stopped doing so on the 15th of October, a period of nearly five months The extraordinarily mild winter enabled us to carry on a lively traffic in goods between the end of the season of 1873 and the beginning of that of 1874, in taking up materials for the construction of two Hotels on Mount Rigi One of these Hotels is on the Rigi line of Arth, the other on the Kaltbad-Scheideck line The Tables appended exhibit the traffic. The second line of rails between the Wasser Station of Freiburgen and Kaltbad was opened to traffic on the 1st of July. It has completely answered our expectations. But owing to the valley line trains which communicated with the Lake steamers being occasionally detained, disagreeable detentions where these lines cross could not sometimes be avoided The thunderstorm of the 29th and 30th of July, threw landslips on to our line in three places This necessitated the closing of the line for one day, viz, the 31st of July, otherwise the traffic has been carried out during the whole season without interruption or accident

2 *Abstract of the trains that were run* —According to the time tables, the following trains ran during the past season —

From 18th of May to 1st of June daily five trains in each direction compared with three in 1873.

From 1st June to 15th September daily eight trains in each direction compared with four and sometimes six in 1873



From 15th September to 15th October daily five trains in each direction compared with three in 1873 Of these trains two were sometimes goods trains, but these in the months of July and August had regularly to be changed to passenger trains Taking the whole there were 5,597 (compared with 3,830 in 1873) up and down trains, giving a train-mileage of 20,778 miles (compared with 15,310 in 1873) Of the above 5,597 trains

2,925 were for Passengers, giving		12,795	train miles
2,672	" Goods, "	7,983	"
	Total,	20,778	"

Out of the 2,672 goods trains, 63 were coupled for the transport of longitudinal sleepers and rails

These figures in 1873 were —

2,669 Passenger trains, giving		11,264	train miles
1,292 Goods	" "	4,266	"
	Total,	15,530	"

3 *Passenger Traffic* —

Travellers in 1874, in their entirety numbered		1,04,394	
" 1873, "	"	96,062	
Or an increase in 1874, over 1873 of		8,332	or 8 67 per cent
Of which in	1874, up traffic,	54,083	" 51 8 "
"	1874, down traffic,	50,311	" 48 2 "
"	1873, up traffic,	49,761	" 51 8 "
"	1873, down traffic,	46,301	" 48 2 "

The seats of the passenger carriages which were occupied were as follows —

Up traffic,	1874, total seats	77,232	Travellers 54,083	or 70 per cent
Down "	1874, "	76,740	" 50,311	" 65⅓ "
Up "	1873 "	71,070	" 49,761	" 70 "
Down "	1873, "	70,884	" 46,301½	" 65½ "

4 *Personal Luggage Traffic* —The appended Abstract Table shows a small decrease in comparing 1874 with the former year, whilst

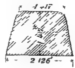
5 *The Goods Traffic* amounted to 9,483 tons in this year, compared with 4,309 tons in 1873 This extraordinary increase was owing to the

CENTRAL-LADDER-RAIL MOUNTAIN RAILWAY, DETAILS OF PERMANENT WAY

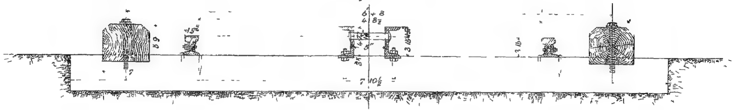
Scale $\frac{1}{18}$ or 8 inches = 1 foot.

Dimensions in feet, inches and decimals of an inch

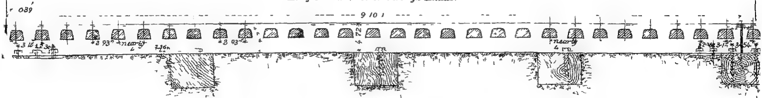
Section of Rung



Cross Section of Permanent Way



Longitudinal Section through Ladder



construction of two Hotels on the Rigi-Kulm and Rigi-First Railways, as well as to the construction of the Arth-Rigi and Kaltbad-Scheideck Railways It must, therefore, in subsequent years be expected to fall off

6 *Managing Expenses* —These amount to the following —

	In 1874	In 1873
	£	£
General Management,	1,137	734
Management of the Line,	1,461	626
Train Service,	1,131	623
Engine Service,	5,790	4,761
	£9,519	£6,744

After omitting much of the above expenditure, which was obviously caused by larger receipts entailing proportionately greater expenses in every department of all the Railways, we still find a larger sum than usual devoted to the wages of the employés in the current year's account The engines have been so completely provided with new axles, rack teeth and cogged wheels, &c, that we do not anticipate that these expensive parts will require anything to be done to them next year But sixteen new bearing wheels will probably be needed

7 *Employés* —80 persons were regularly employed during the season, and 74 persons were employed for occasional daily paid work as it arose, such as tamping permanent way, &c The daily paid works amounted to 4,498¼ working days, which equals the work of about 25 men for a year, calculating the year at 184 working days

IV —Total Receipts and Dividends

		£
As will be seen in the annexed traffic account, the total receipts (including £25 brought forward from the last account) amounted to		24,032
Deduct the expenses,		10,111
Balance remaining,		13,921
Deduct—	£	
Interest at 5 per cent on £40,000 bond capital,	2,000	
The usual dividends on £50,000 share capital, at 5 per cent,	2,500	4,500
		9,421
Deduct—		
1 Extra dividends to the Shareholders on £50,000 share capital at 15 per cent.,	7,500	
2 10 per cent. fees to the Managing Council,	940	8,440
Balance to be carried forward to a new account,		981

According to the above account the coupon due on our shares of £4 will be 20 per cent per share on the 15th December. After the reserve funds had reached the amount of £8,000 according to the statutes we did not find any further addition necessary. But we thought it necessary to found a special reserve fund for building and renewing, which we started with the amount of interest of the reserve fund, viz, £400.

In the name of the Managing Council of the Rigi Railway Company

(Signed) JOST WEBER, *President*

C STŒHELIN, *Secretary and Member*

Note by Translator —The entire annual working expenses on the Rigi (a single line) on a gradient of 1 in 5, appear from the above Report, to have been 9*s* 9*d* per train mile.

Its length is 3·34 miles, of which $1\frac{1}{2}$ miles are laid with a double line. It employed in 1874 ten locomotives and seventeen carriages, and had up to the end of that year cost (including every expenditure in construction and for rolling stock) £26,340 per mile. But the cost of all railway work is greater in Switzerland than in England, and as there is no patent for the Rigi in this country, there is nothing to prevent the permanent way and locomotives being procured in the cheapest market.

Accompaniments to above Report

TABLE I

Building Account of the Rigi Railway Company closed up to the 31st of October, 1874

RECEIPTS	£	£	DISBURSEMENTS	£	£
			(*a*) *Bills paid*		
Balance brought over from last account, .		3,416	1 Locomotive and Machinery manufacture at Winterthur, .	624	
Received 1st instalment from the Reserve Fund of 1873,		3,400	2 Manufacture of Waggons at Freiburgh, .	140	764
Sundries			(*b*) *Building charges and Traffic expenses*		
Interest from the Bank for 1873-74, .	157				
Dividend for 1873 from 50 Regina Montium shares,	26	183	New Buildings and Refreshment Buildings at Vitznau,		5,303
			Transfer of Balance to the Account Current with the Lucerne Bank, . .		932
Total, .		6,999	Total, ..		6,999

Table II

Working Account of the Rigi Railway, closed up to the 31st October, 1874

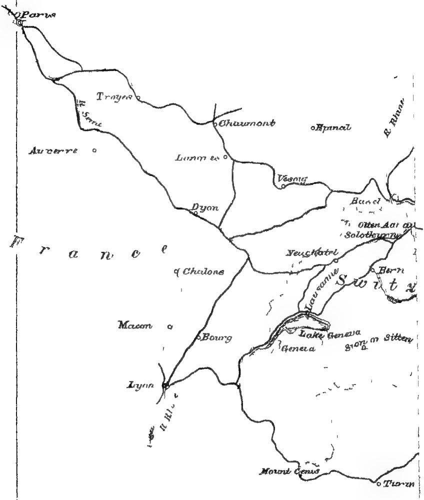
Receipts.			£	£
I Balance of last year				25
II Traffic Receipts				
a Passenger Traffic,		£ 18,701		
Deduct—	£			
Arther Railway,	2,310			
Regina Montium Company,	183	2,493	16,208	
b Baggage Traffic,		415		
Deduct—				
Arther Railway,	18			
Regina Montium Company,	27	45	370	
c Goods Traffic,		7,099		
Deduct—				
Arther Railway,	390			
Regina Montium Company,	306	696	6,403	22,981
III Sundries				
a Rent from Refreshment Rooms at Buden, &c.,			280	
b Rent from Land,			48	
c Sundries,			49	
d Sale of Materials,			593	
e Profit from temporarily invested Capital,			56	1,026
Carried over,				24,032

Disbursements	£	£
I General Management.		
a Guard's wages,	80	
b Managing Director and Assistants,	505	
c Travelling Expenses,	28	
d Rent, Commission, &c.,	31	
e Taxes, Assessments, Imposts,	147	
f Fire Insurance,	44	
g Pay of the Storekeeper	2	
h Printing charges Tickets, Advertisements, Time Tables, Postal charges,	171	
i Contributions to the Charitable Fund of the employes,	46	
k Sundries,	83	1,137
II Railway Management		
a. Salaries of Road Master, Waiters and Workmen,	1,024	
b Upkeep of the Stations and Carriage Sheds,	134	
c Wages of the Store-keeper,	10	
d Bearing rails, rack rails and cogged wheels,	3	
e Sleepers,		
f Bridges, level crossings, slopes, enclosures,	231	
g Telegraph,	15	
h. Sundries,	44	1,461
Carried over,		2,598

TABLE IV

Abstract of the Passenger, Luggage, and Goods Traffic of the Rigi Railway in 1874

	Prior to the commencement of the traffic year		May		June		July		August		September		October		Total	
	No	£	No	£	No	£	No	£	No	£	No	£	No	£	No	£
Passengers, 1874,	461½	82	2,784	536	10,893	2,007	25,900	4,511	40,460	7,193	21,029	3,837	2,866½	535	1,04,394	18,701
" 1873,	42	7	1,770	276	10,344	1,617	26,314½	4,622	36,128	6,486	18,909	3,542	2,556	468	96,063½	17,218
	Tons		Tons		Tons		Tons		Tons		Tons		Tons		Tons	
Luggage Traffic, 1874,			5	6	39	45	100	120	127	156	64	79	9	9	344	415
" 1873,			5	4	30	33	113	129	145	165	63	71	8	10	364	412
	Tons	£	Tons	£	Tons	£	Tons	£	Tons	£	Tons	£	Tons	£	Tons	£
Goods Traffic, 1874,	1,692	1,279	1,473	1,129	1,794	1,315	1,406	935	829	647	1,241	980	1,048	814	9,483	7,099
" 1873,	54	37	542	321	576	436	474	368	661	459	1,126	775	876	675	4,309	3,071



Troyes
Chaumont
Vesoul
Dyon
Basel
Neuchatel
Bern
France
Chalons
Lausanne
Macon
Bourg
Lake Geneva
Sitten
Lyon
Mount Cenis

PROJECT FOR A MOUNTAIN RAILWAY OVER THE ARLBERG

(*From the French*)
[*Vide* Plates XII, XIII, XIV and XV]

Report of Messieurs Riggenbach and Zschokke on the Construction and Working of a Railway over the Arlberg, by means of a railroad with a rack rail (The Rigi system)

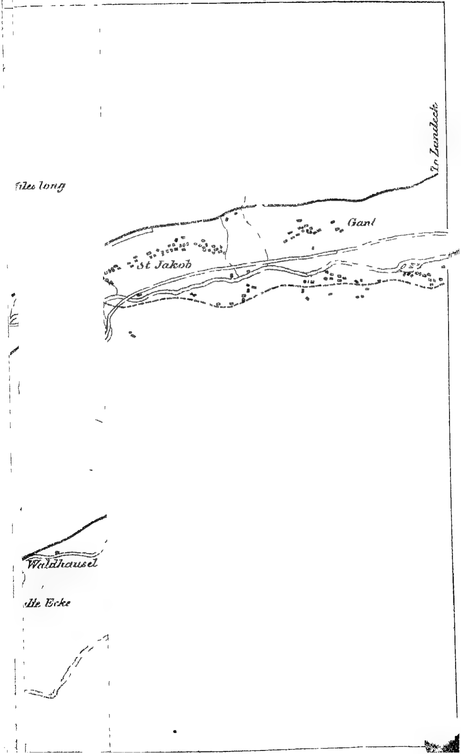
Introduction

Many years ago the Austro-Hungarian Government intended to establish between those important centres of commerce Vienna and Pesth on the one hand, and Switzerland and France on the other, a direct line of communication not passing through Germany This project is now only partly carried out, and consists of the two lines (*a*), from Vienna to Innsbruck *via* Villach and Franzenveste, (*b*), from Pesth to Innsbruck *viâ* Gross-Kanisza and Villach Of the line between Innsbruck and the Swiss Frontier the piece from Bludenz to the Swiss Frontier is alone completed, whilst the central portion between Innsbruck and Bludenz is still under consideration Between these last two points the proposed line must cross the mountains of Arlberg, which rise to a height of 5,906 feet above the sea The Austrian Government proposed to effect the passage of these mountains by means of a tunnel $7\frac{3}{4}$ miles long, the two ends of which would be 3,973 and 4,144 feet respectively above the sea The Austrian Minister estimates the cost of joining Landeck and Bludenz by a railway 43 19 miles long, with a tunnel through the Arlberg, at £1,156,822 (or nearly $4\frac{1}{2}$ millions sterling). The piercing of the tunnel between Klosterle and St Jacob—$7\frac{3}{4}$ miles long—has probably already cost £2,812,106 (or nearly 3 millions sterling) It has been impossible up to the present time to carry out this project on account of its great cost, although it must eminently profit Austria, Switzerland and France For if this projected line from Innsbruck to the Frontier were carried out, Austria and Hungary would thereby be at once connected through the intermediate Swiss Railways with the French net work *viâ* Geneva Pontarlier and Belfort, and in case of a war between France and Germany the transport between France and Austria of goods and particularly grain could be effected over the neutral soil of Switzerland in a perfectly safe manner altogether clear of Germany

Guided by these considerations we will endeavour to prove, that the cost of establishing this important line of communication will be much reduced if our system of mountain railway is adopted. It has already been applied in numerous instances on many parts of the Continent, as for instance on the Rigi, on the borders of Lake Constance, at Pesth-Offen over the Schwabenberg, and at Vienna over the Kahlenberg. The results both from a financial and engineering point of view have been most satisfactory, and have proved this system to be both practicable and advantageous; moreover this new system has answered extremely well in working. We have addressed to the Minister of the Austrian Public Works a report on the railway over the Arlberg, and consider that the great interest which France has in the carrying out of this project justifies us in submitting to the authorities and large Companies of that country the results of our calculations. We would remark, that we only deal here with the calculations concerning the railway over the Arlberg, the immediate object of this report being to establish a comparison between the tunnel project and the mountain railway project. We assume that the very favourable results which the application of this novel system has furnished on the Rigi are known; we rely moreover on the Engineering Report of the Railway through the Arlberg (Bludenz-Landeck) which was published in 1872 at the suggestion of the Minister of Commerce by the Inspector General of Austrian Railways; and we will in addition submit such observations as our own personal experience has suggested to us. We must refer to the annexed plans and sections of the project, and to be brief will designate the Inspector General's project the *existing project*.

I. *The Trace*

The trace actually adopted by the Inspector General rises by gradients of 1 in $34\frac{1}{2}$ from Bludenz to Langen, passes thence through the Arlberg by a tunnel $7\frac{3}{4}$ miles long issuing at Saint Jacob, and descends finally to Landeck with gradients of 1 in 40. In our project on the other hand we limit the gradients from Bludenz to Klosterle to a maximum of 1 in 40, by keeping as much as possible in the valley. From Klosterle we adopt gradients of 1 in $12\frac{1}{3}$ up to where the streams fork at Saint Christophe; thence descending by gradients of 1 in $14\frac{2}{7}$ we rejoin the official trace near Saint Jacob. From this point, as we have already stated, there is an uniform gradient of 1 in 40 as far as Landeck. It will be



files long
St Jakob
Gant
to Landeck
Waldhausel
alle Ecke

thus seen that the two sections over the low country have the same maximum gradient Our reason for adopting over the mountain 1 in $12\frac{1}{2}$ as the maximum gradient on the west side, and only 1 in $14\frac{2}{7}$ on the east is, that the greater part of the traffic will travel from east to west

Distribution of Gradients—The whole length of the Railway from Bludenz to Landeck is 41·889 miles, distributed as follows —

	English Miles
Railway over the low country, with a maximum gradient of 1 in 40 From Bludenz to Klosterle,	15·460
From Saint Jacob to Landeck, . .	16·715
Total miles,	32·175
Mountain Railway with maximum gradients of 1 in $12\frac{1}{2}$ and of 1 in $14\frac{2}{7}$ From Klosterle to Saint Jacob,	9·714
Grand Total miles,	41·889

Table of Gradients

Stations.	Distances	Gradients	Heights above the sea.	Remarks
	Yards,		Yards	
Bludenz, .			611·5	Low land Railway, 15·460 English miles
"	732	1 in 100	618·8	
"	884	1 in $66\frac{2}{3}$	632·0	
"	5,348	1 in 50	739·2	
Bratz, .	166	Level	739·2	
"	4,977	1 in 40	838·5	
Hintergrasse,	328	Level	838·5	
"	3,992	1 in 40	938·3	
Dalaas,	405	Level	938·3	
"	10,029	1 in 40	1,188·0	
Klosterle, .	350	Level	1,188·0	
" .	5,249	1 in $12\frac{1}{2}$	1,607·9	Mountain Railway, 9·714 English miles
Stuben,	219	Level	1,607·9	
"	4,875	1 in $12\frac{1}{2}$	1,957·8	
St Christophe,	328	Level	1,957·8	
" .	6,926	1 in $14\frac{2}{7}$	1,476·4	
St Jacob, .	882	Level	1,476·4	Low land Railway, 16·715 English miles
"	4,769	1 in 44	1,368·1	
Petneu,	393	Level	1,368·1	
"	5,492	1 in 44	1,243·5	
Flirsch,	392	Level	1,243·5	
" . .	5,232	1 in 48	1,121·0	
Strengen,	398	Level	1,121·0	
"	5,468	1 in 40	984·3	
Pians, . . .	374	Level	984·3	
" .	5,645	1 in 40	843·2	
Landeck, .	875	1 in 800	843·2	

Radius of Curves, 820 English feet

II Construction

The low land sections will be carried out according to the existing project The mountain railroad from Klosterle to St Jacob will be laid down according to the Rigi system, with this modification, that the whole length of the permanent way will be protected from the influences of the climate by masonry galleries or iron coverings where necessary The galleries will be provided with ventilators in the roof, and with windows on their right sides to give light

III Time of Construction

The length of time required to construct the line is calculated at 3 years In fixing so long a period we have chiefly to consider the construction of the covered galleries on the Arlberg, for the mere laying down of the railroad will be finished long before that

IV Cost of setting up the line

In calculating the cost we will take the chief details from the official report, excepting the additional items such as covered galleries, permanent way, rolling stock, &c

(a) *Low land lines* —Length 32 175 miles The modification proposed by us in the existing project consists merely in the reduction of the maximum gradients of 1 in $34\frac{1}{2}$ to 1 in 40, by following the lowest line of the valley We can, therefore, take the mileage expenses of this part from the existing project

Hence we obtain the following —

	£
Actual cost of constructing 32 175 miles of low land railway, at £37,755 per mile,	12,14,748
Loss on capital arising from exchange, at 25 per cent,	3 03,687
Interest on the capital sunk for 3 years,	1,13,883
Loss on interest arising from exchange, at 25 per cent,	28,471
Cost of laying down the low land railway,	16,60,789

(b) *Mountain railway* —Length 9 7139 miles Double line

Cost per Mile

		£
1	Office buildings, as in the existing project, ..	192
2	Superintendence, do, ..	644
	Carried over,	836

		£
	Brought forward,	836
3	Purchase of land as in the existing project,	1,213
4	Embankments from analogous examples,	10,575
5	Supplementary works: this head comprises retaining walls, consolidation of the bank slopes, &c.,	6,437
5a	Galleries: The whole line will be protected partly by galleries cut out of the solid rock, partly by galleries of masonry, and partly by roofs of iron. It is well to note here that although we should only allow for the masonry or iron galleries, as those cut out of the rock have been already included under the head of embankments, we have adopted for the whole length of the mountain railway a price per running yard equal to that of a masonry revetment of an ordinary tunnel, viz., £22 17s. 2½d. per yard run,	40,233
6	Small masonry works, as in the existing project,	3,060
7	Large masonry works, as in the existing project,	3,761
8	Ballast, as in the existing project,	977
9	Permanent way (double line) improved system of the Rigi,	17,701.5
10	Buildings, as in the existing project,	2,495
11	Fences and signals, as in the existing project,	793
12	Rolling stock: 10 powerful locomotives with toothed wheels on the improved system of the Rigi, also 40 wagons for covered merchandize,	4,163
13	Sundries, as in the existing project,	242
	Cost per mile,	92,486½

Cost of Construction

Actual cost of constructing 9.714 miles, at £92,486½ per mile,	8,98,414
Loss on capital on account of exchange, at 25 per cent.,	2,24,603½
Interest on the capital sunk during 3 years, at 7½ per cent.,	84,226
Exchange on the interest,	21,056½
Cost of establishing the mountain railway,	12,28,300

Recapitulation

Cost of establishing the low land railway,	16,60,789
Cost of establishing the mountain railway,	12,28,300
Total cost of establishing the line,	28,89,089

V Working Expenses

We have based our working expenses, as in the existing project, on an annual traffic of 4,42,893 tons over the whole length of the line

(a) *Sections of Approach*, (Bludenz-Klosterle and St Jacob-Landeck) —Owing to the maximum gradients of 1 in $34\frac{1}{2}$ adopted in the existing project the trains must not exceed 148 tons in gross weight, which gives a net load of $81\frac{1}{3}$ tons 5,460 trains will therefore be required to transport these 4,42,893 tons By reducing the maximum gradient to 1 in 40 we can, as on the Brenner and Semmering, form trains of 197 tons gross weight, or $118\frac{1}{3}$ tons net weight, drawn by two locomotives, that is to say, the expenses of traction being in both cases the same, 148 tons of gross load will be drawn over the gradients of 1 in $34\frac{1}{2}$, while 197 tons will be conveyed on those of 1 in 40 The annual number of trains will thus be reduced to 3,750 on a length of 32 175 miles, giving a total of 120656 25 train miles Notwithstanding the easier gradients which we have adopted, causing as they will a reduction in the working expenses, we have (to be on the safe side) computed these expenses at the same rate as in the existing project They will thus be —

	s	d
Expenses of traction and maintaining the rolling stock per train mile,	3	$7\frac{1}{2}$
Cost of maintenance and superintendence of the line per train mile,	1	$9\frac{1}{4}$
Cost of general administration per train mile,	1	$1\frac{1}{2}$
Whole cost of working per train mile,	6	$6\frac{1}{4}$

The cost of working 120656 25 train miles of the low land line will thus be annually £39,339

(b) *The Mountain Railway* (Klosterle-St Jacob) —The traction over the Mountain Railway of 197 tons gross weight per train will necessitate very powerful and heavy locomotives, and a consequent increase in the weight of the permanent way Each train of the low land line must therefore be split up on the mountain into two trains, each of $98\frac{1}{2}$ tons gross, or of $59\frac{1}{16}$ tons net weight These mountain trains will be so made up as during the ascent to be pushed by the locomotive and during the descent to be held back by it It may be noted that each of the trains on the low land line being drawn by two locomotives their division into two parts will not necessitate an increased number of locomotives The trains will leave the terminal stations at intervals of 8 or 10 minutes, so as to

follow each other at a distance of about 1,000 yards, in the same way as on the Rigi line, where often five trains follow each other at five minutes intervals It will thus appear that the working of the mountain railway will be altogether different from that on the low land line, and that the two stations Klosterle and St Jacob will have to be considered as stations for breaking up the trains The paying load of each train being $59\frac{1}{16}$ tons 7,500 trains will have to be run to transport 4,42,893 tons If 360 working days be taken in the year 20 or 21 trains must be run daily These 7,500 trains will travel over 9·714 miles, thus giving 72,855 train miles

From these data we will estimate the rolling stock required thus — Assuming an average speed of five miles per hour each locomotive will run backwards and forwards between Klosterle and St Jacob twice in a working day of 8 hours Five or six powerful locomotives will then suffice for 20 or 21 trains to and fro per diem To meet all contingencies we will put down the number at ten As this railway will chiefly carry the wagons of other lines we shall not require so large a number as we otherwise should do, and 40 wagons ought to be sufficient This method of working being agreed to we obtain the following estimate

I Cost of Traction and of Maintenance of the Rolling Stock

	£	s	d
Fuel —On each train mile with a gross load of 98¼ tons, the consumption of fuel will be —			
2·376 cwt in ascending			
·397 „ in descending			
2)2·772			
or 1·386 „ as an average, which at 1*s* 7½*d* gives, . .	0	2	2¾
Oil for Locomotives—·0118 cwts, at £1 17*s* 9¼*d*,	0	0	5
Grease for the toothed driving wheel and rack rail—·0076025 cwts, at 16*s* 9*d*,	0	0	2

Engine Drivers' Wages, &c

	£	s	d
1 Conductor, .	0	8	0
1 Stoker, .	0	4	9½
1 Cleaner, . .	0	2	5
1 Engine workman, . .	0	4	0
Materials, . . .	0	1	7
Sundries, . . .	0	3	2½
Total, .	£1	4	0

	£	s	d
Carried forward,	0	2	9¾

	£	s	d
Brought forward,	0	2	9¾
As each locomotive makes daily four trips of 9 714 miles each, there will be 38 856 train miles Therefore each train mile will cost,	0	0	7¼
Total,	0	3	5

II Maintenance and Superintendance of Permanent Way

These will be required for the whole line yearly

	£
1 Overseer yearly,	100
2 Chief Fitters, at £80 per annum each,	160
15 Railway Watchmen, at £40 each yearly,	600
7,200 days wages of labourers, or 360 days with 20 men on each day at 3s each,	1,080

We must besides estimate for the maintenance of the following items, the cost of constructing which *per mile* will be—

	£	
Galleries,	40,239	
Masonry Works,	6,821	
Ballast,	977	
Superstructure,	1770 5	
Fences and Signals,	798	
Buildings,	2,495	
Cost per mile,	60,020½	
Taking a co-efficient for maintenance of about 7 per cent on the cost of construction, we obtain		4,700
Total,		£66,610

	s	d
These working expenses are distributed over 72,855 train miles Hence the cost *per train mile* will be	1	9½

III Cost of General Administration

	s	d
Taking this as in the existing project, which has a long tunnel, the cost *per train mile* will be	1	1½

Recapitulation—The working expenses of the mountain railway *per train mile* will thus be—

		s	d
1	Traction and maintenance of rolling stock,	3	5
2	Maintenance and superintendance of permanent way,	1	9½
3	General administration,	1	1½
	Total,	6	4

	£
Thus for 72,855 train miles of mountain railway, a total is obtained of	23,070

The whole working expenses on all the line will thus amount to annually—

		£
1	On the low land line,	39,339
2	On the mountain railway,	23,070
	Total,	62,409

which sum capitalized at 5 per cent represents a capital of £12,48,180.

VI *Comparative Table of leading features*

	Railway with long tunnel, (*the existing project*)	Mountain railway with rack rail, (*proposed project*)
Length of line without tunnels, or over the low land,	31 707 miles	32 175 miles
Length of line in tunnelling, or length of mountain railway,	7 86 miles	9 714 miles
	39 567 miles	41 889 miles.
Height above the sea of highest point,	4,186 feet.	5 873 feet.
Maximum gradient of low land lines,	1 in 34½	1 in 40
Maximum gradient of mountain railway,		1 in 12½
Difference of level in the ascent,	2,323 feet	2,310 feet
Do do descent,	1,571 feet.	1,444 feet
Whole difference of the heights,	3,894 feet	3,754 feet.
Average gradient over whole length,	1 in 58	1 in 47, low land line 1 in 13½, mountain railway
Radius of sharpest curves,	820 feet	820 feet.
Time required for construction,	8½ years.	3 years.

RAILROAD WITH LONG TUNNEL (*existing project*)

I Cost of Railroad on either side of the tunnel

		£	
1	Office Buildings,	192	
2	Superintendence,	644	
3	Purchase of Land,	1,213	
4	Embankments,	6,328	
5	Supplementary Works,	9,778	
6	Small Masonry Works,	3,060	
7	Large Masonry Works,	3,761	
8	Ballast,	977	
9	Permanent Way,	4,490	
10	Buildings,	2,495	
11	Fences and Signals,	793	
12	Rolling Stock,	3,783	
13	Sundries,	242	
	Actual cost of construction per mile,	37,756	£
	Therefore cost of 31 863 miles,		12,02,988
	Loss on capital from exchange, at 25 per cent,		3,00,747
	Interest on the capital sunk for 3 years, at 7½ per cent,		1,12,781
	Exchange on the interest,		28,195
	Cost of the railway on both sides of the tunnel,		£16,44,711

II Cost of the Tunnel (double line)

	£	
Actual cost of 7 705 miles from the detailed estimate,	17,99,748	
Loss from exchange, at 25 per cent.,	4,49 937	
Interest on the capital sunk for 8½ years,	4,49,937	
Exchange on the interest,	1,12,484	
	28,12 106	
Cost of the Tunnel,		28,12,106

Entire cost of establishing the Line,	£44 56,817

Saving in cost of Const

MOUNTAIN RAILWAY WITH RACK RAIL (*proposed project*)

I Cost of low land sections

		£	£
1	Office Buildings,	192	
2	Superintendence,	644	
3	Purchase of Land,	1,213	
4	Embankments,	6,328	
5	Supplementary Works,	9 778	
6	Small Masonry Works,	3,060	
7	Large Masonry Works,	3,761	
8	Ballast,	977	
9	Permanent Way,	4,490	
10	Buildings,	2,495	
11	Fences and Signals,	793	
12	Rolling Stock,	3,783	
13	Sundries,	242	
	Actual cost of construction per mile,	37,756	
	Therefore 32 175 miles will cost,		12,14,767
	Loss on capital from exchange, at 25 per cent.,		3,03,692
	Interest on the capital sunk during 3 years, at 7½ per cent,		1,13,882
	Exchange on the interest,		28,470
	Cost of the low land section,		£16,60,811

II Cost of the Mountain Railway (double line)

		£	s	
1	Office Buildings,	192		
2	Superintendence	644		
3	Purchase of Land	1,213		
4	Embankments,	10 575		
5	Supplementary Works,	6 437		
5a	Galleries,	40,233		
6	Small Masonry Works,	3,060		
7	Large Masonry Works,	3,761		
8	Ballast	977		
9	Permanent Way,	17,701	5	
10	Buildings	2,495		
11	Fences and Signals,	793		
12	Rolling Stock,	4,163		
13	Sundries,	242		
	Actual cost of constructing one mile, £	92,486	10	
	Therefore 9 714 miles will cost,	8,98,414		
	Loss on capital from exchange, at 25 per cent,	2,24,603	10	
	Interest on the capital sunk during 3 years, at 7½ per cent,	84,226		
	Exchange on the interest,	21,056	10	
		£ 12,28,300	0	
	Cost of Mountain Railway,			12,28 300
	Entire cost of establishing the Line,	.		28,89,111

ruction, £15,67,706

Comparative Table of Cost of Working for an Annual Traffic of 4,42,893 tons of Merchandise on both lines

MOUNTAIN RAILWAY WITH LONG TUNNEL (*existing project*)

For the whole line, with a maximum gradient of 1 in 34½

	s d	
Cost of traction and of maintenance of the rolling stock,	3 7½	per train mile
Cost of maintenance and of superintendence of the line,	1 9¾	"
Cost of general administration,	1 1½	"
Cost per train mile,	6 6¾	

	£
5,460 trains, of a net weight each of 81⅛ tons, which are required annually to convey 4 42,893 tons over a distance of 39 567 miles, will give 2,16,036 train miles, which at 6s 6¾d per train mile gives,	70,437
Whole annual cost of working,	70,437
Which capitalized at 5 per cent, represents a sum of	14,08,740

MOUNTAIN RAILWAY WITH RACK RAIL (*proposed project*)

(*a*) *For the low land sections, with a maximum gradient of 1 in 40*

	s d
Cost of traction and of maintaining the rolling stock	3 7½
Cost of maintenance & superintendence of the line,	1 9¾
Expenses of general administration,	1 1½
Annual cost per train mile,	6 6¾

	£
3,750 trains, of a net weight each of 118⅛ tons, which are required annually to convey 4 42,993 tons over a distance of 32 175 miles, will give 1,20656 25 train miles which at 6s 6¾d each train mile gives,	39,339

(*b*) *For the Mountain Railway, with a max gradient of 1 in 12½*

	s d
Cost of traction & of maintaining the rolling stock,	3 5
Cost of maintenance & superintendence of the line,	1 9½
Expenses of general administration,	1 1½
Annual cost per train mile,	6 4

	£
7,500 trains, of a net weight each of 59 1/16 tons, which are required annually to convey 4 42,893 tons over a distance of 9,714 miles, will give 72,855 train miles, which at 6s 4d each gives,	23,070
Whole annual cost of working,	62 409
Which capitalized at 5 per cent, represents a sum of	12,48,180

Saving, £1,60,560

The entire cost of Construction and Working

	Tunnel Railway	Mountain Railway
Cost of construction,	£ 44,56,817	£ 28,89,111
Cost of working capitalized,	„ 14,08,740	„ 12,48,180
Total	£ 58,65,557	£ 41,37,291
Whole saving,	£ 17,28,266	

VII —Conclusion

(*a*) In the cost of establishing the railway, a saving of £15,67,706 is thus shown in favor of the rack rail system This saving arises in a great measure from the suppression of the tunnel, and ought to be considered if anything below the mark, because in our opinion even the approximate cost of piercing a long tunnel is beyond all ordinary calculation, and may very likely prove too small In the cost of working capitalized a saving of £1,60,560 is shown in favor of the rack rail system The financial results both in construction and working are thus entirely in favor of our project

(*b*) The first objection which may be raised to our project is, that we cross the top of the mountains at an altitude of 5,873 feet —or 1,686 feet higher than is done in the existing project, and that this will consequently expose our railway during winter to very unfavorable climatic influences To this we would reply, that our estimate allows for the mountain railway being protected throughout its length against the inclemences of the winter by galleries admitting light, and affording an escape for the smoke of the engine If this arrangement proves successful it cannot be doubted that the railway will be able to run at an altitude of 5,873 feet without interruption to its service It is equally also beyond doubt, that if the Rigi Railway was protected by galleries the trains could run regularly during the severest winters to Kulm, that is to the same height of 5,873 feet above the sea

(c) It might also be objected that the wear of the rack-rail system will be considerable But we reply that the experience on the Rigi during four years has shown that this wear is quite insignificant, and even less than that of ordinary railways, in fact, there is an economy under this head which we have not allowed for in our calculations

(d) As for the safety of the ascent and descent, it has been proved on the Rigi, that it is at least as great as on ordinary railways, one reason being the slow speed of the trains, and the other the adoption of powerful breaks, which can effect the immediate stoppage of the train On the Rigi there has never been the smallest accident in spite of its very heavy traffic and its gradients of 1 in 4

(e) With regard finally to the working of the railway, it might perhaps be considered irrational that all trains running the whole length of the line must be raised up to a height of 5,873 feet, leading thereby to an increase in the work done, and so far burdening the cost of working But we would observe, that if this height were crossed by means of a railway trusting only to adhesion on a gradient of 1 in 40 or 1 in 33½ the annual cost of working it would be much increased, and would far exceed the interest on the capital outlay on the tunnel, as owing to the liability of the locomotives to slip a much greater expenditure of steam would be required With the rack rail system on the contrary there is no slipping, and the whole of the steam generated by the locomotive is utilized in producing motion The results of the preceding calculations in other respects fully confirm what we have said

	£
The annual saving in working consequent on the adoption of the Mountain Railway will be,	8,020
Interest at 5 per cent on the sum saved by the rack rail construction,	97,983
Total annual saving,	£ 1,06,003

which will consequently permit of a reduction of 36½ per cent. in the tariff, or in the cost of transport allowed for in the existing project

In conclusion, we believe we can state with perfect truth, that the adoption of our project for a railway over the Arlberg will afford the important advantage of reducing the capital outlay by about £1,740,000 without any drawback to the working of the railway in respect to its international character

AARAU,
27th November, 1874

Note by Translator—It has by many been supposed that the Rigi system could only meet a large passenger traffic, but it is now proposed for an annual traffic of nearly 4,50,000 tons, or a daily traffic of from 1,500 to 2 000 tons To carry this traffic it is to be laid on a gradient of 1 in 12½, this being the same gradient on which Fell's system has been laid in Brazil But whereas Fell's engine has only been able to drag 27 tons, the Rigi engine is calculated to push up 60 tons of paying load on this gradient On the Arlberg (a double line) the entire working expenses are calculated at 6*s* 6*d* per train mile, but the cost of the traffic service (such as wages of ticket collectors, porters, &c,) seems to be omitted The following figures are obtained from the above report —

	Number
Number of engines per mile worked,	97
Train mileage per engine per annum,	7,285 5
Running expenses, repairs and renewals per engine per annum,	£ 1,244

The accompanying comparative Tables will probably be of service

TABLE IA

Comparative Table of the Working Expenses of different Railways, per train mile

Daily Traffic in tons	Railway	I. Cost of traction and of maintenance of the rolling stock per train mile				II. Maintenance and superintendance of permanent way per train mile			Total of I and II	III. General Administration	Remarks
		Fuel	Oil and Grease	Wages and upkeep	Total	Maintenance	Superintendance	Total			
		Pence	Pence	Pence	Pence	Pence	Pence	Pence	Pence	Pence	
60	Ladder Rail over Rigi, gradient 1 in 4,	22	8½	36¼	66¾	4½	12¼	16¾	83½	13	Single Line
1,500 to 2,000	Ladder Rail over the Arlberg, gradient 1 in 12½,	26¾	7	7¼	41	Not known	Not known	21½	62½	13½	Double Line—proposed, not yet executed
640	San Paulo, Brazil, stationary engine, 1 in 9 75,	19	2¼	26¼	47½	6½	Not known	Maintenance alone 6½	54	Not known	Single Line.
640	San Paulo, Brazil, locomotive line, 1 in 40,	13½	2	20	35½	23½	Not known	Maintenance alone 23½	59	Not known	Single Line
100	Fell's System, Mont Cenis, 1 in 25,							•	54	15	Single Line
200	Mauritius Railway, 1 in 30,	11	1¼	14¼	26½	Not known	Not known	38½	65	Not known	Double Line
	English Railways, (average) mostly very easy gradients	4	2¾	11¼	18	9	Not known	Maintenance alone 9	27	Not known	Double Line
950	Madras Railway, gradient 1 in 100,	7¼	½	17½	25¼	13	2¾	14¾	40	5¾	Single Line.

R	of Permanent Way and Works per train mile	Locomotive expenses per train mile.	Cost of repairs and renewals of Rolling Stock per train mile	Traffic charges per train mile	Maintenance and renewal of Works per ton carried including Passengers and Luggage	Locomotive expenses per ton carried, including Passengers and Luggage	Repairs and renewals of Rolling Stock per the ton carried including Passengers and Luggage	Traffic charges per ton carried including Passengers and Luggage.
	ence	Pence	Pence	Pence	Pence	Pence	Pence	Pence
London and No	5 50	8 47	2 73	10 58	6 51	10.02	3 23	12 52
Great Western,	6 59	7 93	3 05	9 19	8 60	10 35	3 98	12 00
Great Northern	5 53	9 01	2 48	8 04	9 30	15 12	4 18	13 51
North Eastern,	6 12	10 20	4 74	6.40	3 76	6 59	2 91	3 94
Great Eastern,	6 29	9 48	2 99	11 23	8 52	12 82	4 05	12 66
London and Bri	6 45	11 11	2 75	10.93	6 55	14 72	3 64	14 48
South Eastern,	6 88	8 94	2 52	11 34	9 92	12 88	3 64	16 34
Cambrian, ..	9 81	5 90	2 65	8 33	15 41	9 28	4 17	13 10
Caledonian,	6 01	8 06	1 88	7 04	5 11	6 86	1 60	6 00
North British,	7 41	6 84	3 32	8 48	6.61	6 10	2 96	7 05
Highland, .	3 70	6 32	2 30	8 71	9 48	16 14	5 88	22 25
Great Southern	8.13	9 91	2 08	7 23	18 90	23 49	4 84	16 83
Dublin and Drog	6 72	7 56	2 20	6 08	14 47	16 20	4 73	13 08
Grand Trunk of	11 34	15 17	5 22	12 97	22 18	61 08	21 00	52 20
Festiniog,	4 91	5 35	3 60	10 39	3 24	3 54	2 38	6 87
East Indian and	10 27	26 20	3 78	8 32	28 03	61 84	13 88	32 99
Bombay and Bar	20 06	24 71	11 09	5 73	47 00	57 90	26 00	26 85
Eastern Bengal,	12 13	15 43	2 55	8 03	15 65	19 92	3 29	20 72
Madras Railway,	13 79	14 66	2 39	6 71	54 79	58 26	9 51	26 66
Rigi Mountain ra	4 93	56 81	10 15	25 00	6 26	72 19	12 90	31 77

No. CLXXXVII

FORMATION OF A HARBOUR AT MADRAS

[*Vide* Plates XVI and XVII]

Report by W PARKES, ESQ, M I C E, *to Govt, Fort St George*

Dated Madras, 4th November, 1873

SIR,—In accordance with instructions given to me by the Secretary of State for India, at the request of the Government of Madras, I arrived at this place on the 29th September, and was engaged for the five following weeks in prosecuting such personal inquiries, observations and investigations as I considered necessary to enable me to submit to you my conclusions as to the best mode of providing shelter for shipping.

2 *Sources of information*—I have received every possible assistance from the officers of all the Government Departments to whom I applied, from those of the Madras and Carnatic Railway Companies, and also from several of the leading Merchants of the place, and from the Secretary of the Chamber of Commerce I have also had opportunities of conferring, with the Commanders of several of the ships lying in the roads at the time of my visit, and have received from them valuable information on nautical points

3. *Previous study of the question*—It is right that I should state at the outset, that my attention had been given to the subject for some time previous to my receiving official instructions to report, and while in England, I had the advantage of repeated conferences with Captain A D Taylor, I N, an Officer of great experience and eminence as a Marine Surveyor of this coast, and also with Mr J J Franklin, R N, for many years

Secretary of the Marine Board of Madras, as well as with other gentlemen of local experience then in England

4 *Invitation to visit Madras*—As a result of the information thus obtained, I felt myself justified in submitting to His Excellency the Governor of Madras, in August 1872, some remarks, in which I called in question the correctness of certain conclusions which had then recently been laid before the Government and were under its consideration It was, I believe, in consequence of this that I was invited to undertake a personal investigation of the whole question on the spot In doing this, however, I have subjected all my previous conclusions to the most rigid tests, and though those which I have now to submit are substantially the same, yet I am enabled to base them on information locally obtained, and I can put forward my recommendations in a more complete form, and my estimates of cost and of results to be obtained with greater confidence

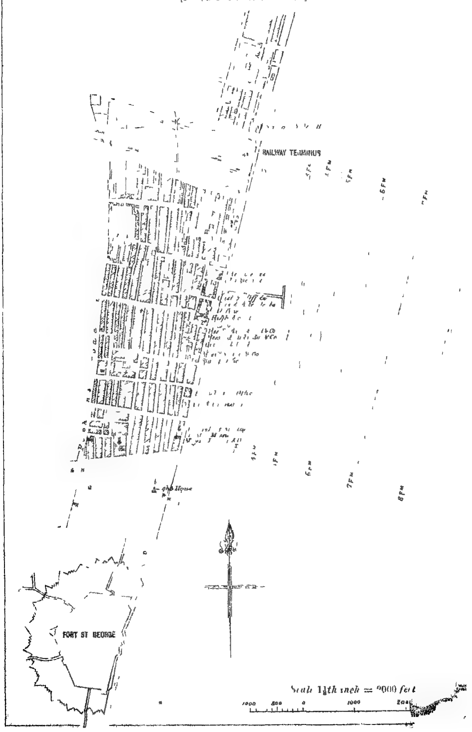
5 *Blackwood's Harbour and inland docks*—I have not thought it necessary to devote much time to considering the details of two proposals which, in former times, have met with some support, because it appeared to me that neither was calculated to effect the object in view These are, *first*, the removal of the trade of Madras to some locality, such as Blackwood's Harbour, more favoured by nature, and, second, the formation of inland docks and basins

6 *Breakwater and close Harbour*—The two proposals between which the choice now lies, are, first, a breakwater entirely detached from the shore, and parallel to it, and, second, a harbour formed by piers running out from the shore into deep water, and termed a "close harbour"

7 The former of these systems is advocated from two totally different and independent points of view, and, so far as I am aware, no one (unless the Master Attendant, whose recorded opinion I shall presently quote at length, be an exception) advocates it on both grounds

8. *Breakwater Committee*—The Committee appointed by Government in 1868, known as the Breakwater Committee, reported in January 1869, as follows, paragraph 40—"If it were possible to construct an enclosed harbour, which should be secure from the danger of shoaling up, we should not hesitate to recommend it in preference to a breakwater. It would be greatly superior to the latter in every respect The piers would be constructed from the shore, and at far less expense in proportion to the material used than the breakwater, the accommodation for shipping and

PLAN OF THE TOWN, AND ROADSTEAD OF MADRAS



the facilities for landing and shipping cargo would be greatly superior to those afforded in an open harbour But we consider that all these advantages would be rendered nugatory by the shoaling of the harbour, which would certainly result from the construction of any solid piers or groynes from the shore, and we are strongly of opinion that a breakwater is the one work from which any real improvement is to be hoped " Such is the view held by one class of advocates for the breakwater system

9 *Mr Robertson*—Mr Robertson, Harbour Engineer for India, says, (Reports, first series, p 62) —"I have come to the same conclusion as the Committee, but from entirely different reasons I have shown that there *may* be as much, if not more, danger from shoaling in the case of a breakwater as of an enclosed harbour, but taking all the circumstances connected with Madras into consideration, a breakwater appears to me to be preferable to an enclosed harbour For an equal sum of money it will give much more *deep* water shelter than a harbour, it will create a considerable length of sufficiently smooth water at the coast line to enable boats to land or to come to jetties, and vessels can enter and quit more easily from behind a breakwater, than through the one entrance of a harbour."

Thus, in Mr Robertson's view, the shoaling objection would, if valid, be equally fatal to either system, but his opinion as to its validity, though not expressed, is, I cannot but think, very clearly implied to be in the negative

10 *Sir Arthur Cotton*—Sir Arthur Cotton in the able and suggestive paper he gave me before I left England, and which the Government at my request has printed and distributed, is less reticent. He argues from facts within his own experience, that the along shore movement of sand is not sufficient to interfere with the success of an enclosed harbour, but he prefers the breakwater on grounds very similar to those expressed by Mr Robertson, being mainly of a nautical character Similar views are I believe held by others whose opinions are entitled to every consideration.

11 *Fear of shoaling, groundless*—I agree with Sir Arthur Cotton that the fear of shoaling either in the case of a breakwater or of an enclosed harbour is groundless, and I agree with the Breakwater Committee in their opinion as to the superior advantages of an enclosed harbour

Advantages of breakwater exaggerated.—I further think that both classes of advocates of the breakwater have much over-estimated the ad-

vantages to be derived from it I have now to give my reasons for these conclusions

12 *Grounds of fear as to shoaling not definitely given* —First, as to the fear of shoaling The Breakwater Committee and the professional witness by whose opinion they appear to have been mainly influenced Colonel (now Major-General) C A Orr, R E, have expressed their conclusions upon this point in the most emphatic and confident terms But in searching for the grounds of these conclusions, one cannot but be struck with the comparatively hesitating and indefinite terms in which those grounds are expressed The Committee, in their remarks on Mr Fraser's project for a close harbour, say "We consider there is strong reason to conclude that if a beach is extended a hundred yards by means of groynes, it might be extended a hundred yards further by continuing the process, and in each case a new line of beach being formed precisely similar to the original beach, there would appear to be nothing to prevent the shore being extended to any amount that might be desired "

13 *Colonel Orr* —Colonel Orr passes over the matter very lightly in his evidence, but in a memorandum by him appended to the report, he says "It is evident to all who have had opportunities of studying the circumstances of the Madras beach, that any obstruction opposed to the currents must necessarily have the effect of arresting the passage of the sand which is in constant movement by the combined action of the surf and those currents, and of causing it to accumulate to windward of the obstacle The accumulation would at first form merely an extension of the beach seaward in the angles between the training walls and the shore, but it would ultimately, I have no doubt, carry the line of the coast to the outer end of those walls, and close the entrance between them "

14. *Period required for advance of Coast line not estimated* —The natural process is, I believe, correctly described by Colonel Orr, but evidently the practical conclusion depends upon the meaning we are to attach to the indefinite term "ultimately" Does this refer to a future time to be reckoned by years, by generations, or by centuries? I presume that neither the Committee nor Colonel Orr, can have meant to assert that the second hundred yards would accumulate as fast as the first, the third as the second, and so on They cannot have failed to take into consideration that every hundred yards of advance of the beach involves a greater

depth of water to be filled, and a greater length of coast to be covered by the triangular accumulation, and consequently a slower rate of advance for every successive hundred yards But evidently they can have made no attempt to form even an approximate estimate of the decreasing rate of advance

15 *Rate of advance decreasing*—I might quote many instances of groynes, piers and other obstructions carried out from sandy beaches similar to that at Madras, in which the rate of advance has been rapid at first, but in a few years so slow as to place the ultimate extension of the sand to the head of the obstacle in so distant a future as to render it practically no element in the question It might be urged with respect to any one instance that the circumstances are different to that of Madras, but the cases are now so numerous as to throw the *onus probandi* on those who assert that Madras is an exceptional case In some of the cases there were predictions of the same nature, and as positive as those given in regard to Madras, but in every instance they have been signally falsified There are plenty of instances of *small* groynes being buried and *small* harbour entrances being choked by sand, driven along the beach as Colonel Orr describes, but in every case in which piers on a large scale have been carried out, the advance of sand has been left far behind I spent much time before I left England in investigating the history of all the cases of which I could find any record, and satisfied myself that the general rule is as above stated, and that Madras might legitimately be concluded to be subject to the same rule, unless reason could be shown for its being an exception

16 *Sir Arthur Cotton's experience*—Upon this point the evidence of Sir Arthur Cotton is of the highest value He had constructed groynes on the beach at Vizagapatam, and had carefully watched and recorded their effects Those effects were of the same character as I have described above, and Sir Arthur had subsequently an opportunity, while Chief Engineer at Madras, of comparing the circumstances of that beach with those of Vizagapatam He saw no ground for supposing them to be materially different, and unhesitatingly applied his Vizagapatam experience to the case of Madras

17. *Records of effect of Groynes*—Since my arrival at Madras, I have gone a step further I have searched the whole of the records in the office of the Chief Engineer in connection with the accumulation of sand

by the groynes constructed some years ago I found it reported that when the groynes were short, the spaces between were quickly filled with sand, but when they were longer, one season was not sufficient for the accumulation On one occasion in 1857, an estimate was made by Captain Rawlins, the Engineer in charge of the groynes, of the quantity of sand accumulated in a season by the groynes in front of the fort, and by that opposite the light-house, and those opposite Messrs Arbuthnot's and the Custom-house The area was in the aggregate $22\frac{1}{2}$ acres, and the depth three to four feet, and the spaces were not filled Taking this, therefore, as a measure of the quantity of sand which could be arrested in one year, I found that in order to fill in a triangular area of similar form between the coast and a pier extending 1,200 yards from shore, a period of 180 years would be required

18 *Experience of other places*—This result though of course only approximate, is so completely in accordance with the experience of other places, as to remove all doubt that the accumulation of sand at Madras will not be so rapid as to cause any practical inconvenience to a harbour formed by piers running out from the shore I may mention three cases in which definite results have been obtained —At the harbour of Great Yarmouth, on the east coast of England, exposed to a drift of sand from the northward, that drift was arrested for forty years by a pier less than 200 feet long, at the port of Bayonne in France, situated at the southern extremity of a line of several hundred miles of sandy coast, exposed to the heavy north-westerly seas of the Bay of Biscay, works constructed just within the shore line 300 years ago, are now 1,200 yards inland, at Port Said, exposed to a constant drift from the westward, the experience of ten years furnishes data, according to the Admiralty Chart of 1870, for the conclusion that 150 years will elapse before the wave-driven sand can pass the pier head, which is now 2,200 yards seaward of the present coast line

19 *Supposed advantages of Breakwater*—I stated in paragraph 11 that I considered the advocates of the breakwater had over-estimated the advantages to be derived from it This conclusion is not based on the examination of any definite estimate of such advantages, for none such has been put on record, but rather from the statements of existing evils which it is assumed the breakwater would remedy The nearest approach to an estimate is that given by Mr Robertson, and quoted in paragraph

9, viz, that it would give more deep water shelter than an enclosed harbour of the same cost, and that it would create a considerable length of sufficiently smooth water at the coast line Sir Arthur Cotton considers that "the breakwater would leave the space behind it exposed to a ripple from northerly or southerly winds, but *not to any swell*"

20 *Want of data for estimating effect of Breakwater* —These are certainly very vague estimates on which to base a recommendation for so large an expenditure, but that they are not more precise is due to the fact that there exists no experience, and even no theory on which such an estimate could be based Mr Thomas Stevenson, in his valuable treatise on Harbours, states that he has "been unable to find that a single observation or experiment of any kind has been made upon the subject"

That there will be some shelter behind a breakwater lying parallel or nearly so to the ridges of the advancing waves, we cannot doubt, but there are absolutely no means of judging better than the merest guesses to what extent the deflected waves will roll in through the wide spaces at either end, and what length of breakwater would be necessary to prevent them from meeting in the space between it and the shore, and creating cross and confused seas more troublesome to ships, and more dangerous to boats then the regular swell of the ocean Where the length of breakwater is sufficient to allow the waves entering from either end to spend themselves, and leave a space between, in that space there will be complete shelter Whether the length of 2,000 yards is, or is not sufficient for this purpose, I cannot say positively. If I were to hazard a guess, it would be that it is insufficient

21 *Direction of Seas* —So far I have assumed that the seas will advance upon the breakwater from that direction which gives it the greatest advantage, that is at right angles or "broadside on," or in the case of Madras from the eastward But it is evident that to a sea setting from the northward or the southward, the breakwater would be "end on" and of no use whatever Probably no great force of sea ever comes from these quarters, but I am informed that during the north-east monsoon, the waves, though breaking nearly parallel to the shore, have, at the distance at which it is proposed to place the breakwater, a direction much nearer to that of the wind which raised them, and would therefore strike the breakwater very obliquely. This would reduce the width of the sheltered area, and the sheltered part of the beach would be somewhere near

the light-house instead of opposite the business part of the town A work which would offer so little protection during the annual foul weather season would not do much for the port

22 *Comparative shelter of Breakwater and closed Harbour* —From what I have said of the uncertain character of the shelter to be obtained from a breakwater such as proposed, it will be easily understood that I cannot bring to any definite test Mr Robertson's opinion, that it would provide more deep water shelter than a closed harbour of the same cost I will, however, for the moment assume that the shelter would be as complete as its advocates appear to think On such an assumption, the number of ships that could be moored on the same system would be about equal in the two cases On the most favourable assumption, the breakwater will not therefore give the superior accommodation claimed for it

23 *Effect of Hurricanes* —Sir Arthur Cotton says that this question of shelter for shipping is not to be settled by what happens in a hurricane In this I quite agree I doubt whether any plan would give absolute immunity from danger during such exceptional times, still it is desirable to ascertain precisely what are the dangers to which shipping are exposed at such times, and what will be the effect of works intended for their protection in more ordinary times

24 *Description of Hurricanes* —I think, with this view, it may not be without use for me to present, in a more definite form than is ordinarily accessible, the leading features of the hurricanes which occasionally visit Madras It does not fall to the lot of many persons to be eye-witnesses of more than one or two of these severe storms, and this partial experience is apt to lead, either on the one hand, to a too hasty generalization, or on the other, to an equally hasty conclusion that the phenomena manifested are incapable of being definitely classified

25 *Observatory records* —To enable me to do this, I have been favoured by Mr Pogson with not only a sight of the complete meteorological records of the Government Observatory, but also with his personal assistance in extracting from them the leading features of the several storms which have occurred since 1787, a period of over three-quarters of a century

26. *Three classes of Hurricanes* —I give in an Appendix the extracts which we made, and I now submit the general conclusion to be drawn from that statement A very little study of it will show that the storms may be divided into three distinct classes, and the generally ac-

cepted theory of revolving storms or cyclones, identifies these classes as those in which the centre of the storm passes respectively over Madras, or south, or north of it

27 *First class—central* —Storms of the first class occurred in October 1797, May 1811, October 1818, and October 1836 In all these cases the wind commenced at or near north, blew for some hours with great force, then there was a lull of half an hour or less, and then it blew again with equal violence from the south In no case, except perhaps in 1811, as to the particulars of which there appears to be some doubt, did the wind come at any time from the eastward

28 *Second class—centre south of Madras* —Storms of the second class, centre south of Madras, occurred in December 1807, November 1846, November 1848, May 1850, November 1864, November 1865, and May 1872 In each of these seven cases, the same course was followed, the wind rose at about north, then gradually increasing in force it veered towards east, maintaining its force After passing east it gradually fell, and by the time it arrived at south, was either very light or merged in the ordinary periodical wind

29 *Third class—centre north of Madras* —Storms of the third class, centre north of Madras occurred in November 1787, May 1788, March 1820, May 1827, May 1841, May 1843, October 1846, May 1851, and November 1856 In these ten cases, the courses of the wind were much less regular than in the two preceding classes It kept rapidly shifting about with apparent irregularity through the *western* half of the compass, never during the height of the storm being in the *eastern* half, except on one remarkable occasion (October 1846), and perhaps one or two other of the earlier ones, when it made a rapid circuit of the whole compass round by west, north, east and south

30 *Summary* —It thus appears that in only one out of the three classes (with the one exception just noted) did the wind blow from the east, in only one from the south with any force, but in all from the north I may add that strong winds never blow from the eastward at Madras, except at the tails of the one class of cyclones

31. *Preponderance of northerly winds—direction of waves* —This statement shows that in extraordinary as well as in ordinary weather there is a great preponderance of strong northerly wind. During ordinary times it is the north north-east wind of November, and December alone,

or rather the sea raised by it, which interferes in any serious degree with the trade of the port as carried on the present rude system It is of course from the waves rather than from the wind that shelter is required, and these no doubt in the gradually shoaling water advance from a more easterly quarter, but the assumption that they come from a direction nearly at right angles with the proposed breakwater is not borne out by the information I have received If the question between a breakwater and an enclosed harbour depended upon this, it ought to be made the subject of more systematic observation before assigning any precise weight to the argument, but I have no hesitation in saying that a roadstead exposed to the most prevalent and strongest *winds*, even irrespective of the direction of the heaviest *seas*, cannot be considered to be effectually sheltered

32 Having now shown that the only objection to an enclosed harbour which has been put forward as fatal, is groundless, and that the advantages to be derived from a breakwater are very uncertain as to their extent, and on the most favourable assumption very incomplete, it only remains for me to describe the work which I consider most suitable to the locality and the circumstances

33 *Principles on which design is based* —In determining upon the scale of my design, I have endeavoured to keep in view the following principles first, that it should be sufficient for, but not in excess of, the present requirements of the trade, second, that it should be capable of extension if it should become necessary to provide for an increase of trade, or greater accommodation for shipping, and third, that the outlay upon it should not render necessary increased expenses in the trade of the port, so as to enhance the cost of goods exported or imported, or throw any permanent burden on general or local revenues

34 Whether this last condition is absolutely necessary, it is not for me to say, but if it can be fulfilled it is undoubtedly a desirable one, as it would render the undertaking at least self-supporting if not pecuniarily profitable

35 *Source of Revenue* —The source to which I look for revenue to pay interest on the necessary outlay is the appropriation of the saving which may undoubtedly be effected upon the expenses to which the trade is exposed by the present rude system of landing and shipping cargoes. This is not only very costly in itself, but it subjects the cargoes to much damage in their passage between the ship and the shore, and by the slow-

ness, awkwardness, and uncertainty of the operation, causes great detention of the ships The removal of all these evils may be represented by a money value which may in some form or other be carried to the credit of a harbour revenue

36 *Present system very expensive* —In what particular form the charge should be levied is for the present an immaterial question I am now only concerned to show that such a saving is possible, and that it would be on a scale commensurate with the required interest on the capital to be sunk In proof of this I would refer to the accompanying table which shows the comparative cost by official tariff of landing and shipping cargo at Madras, as an open roadstead and at Kurrachee, a smooth-water harbour The charges for lightering to and from the roads outside the harbour at Kurrachee (now however never incurred) are given to show their general coincidence with the Madras charges under similar conditions

Comparison of the Cost of Landing and Shipping Cargo at Madras and at Kurrachee from Official Tariffs

	Madras			Kurrachee					
	Fair Weather*			Harbour			Roads		
Imports	RS	A	P	RS	A	P	RS.	A	P
Piece goods per 100 bales,	34	6	0	25	0	0	35	0	0
Grain per 100 bags,	11	0	0	4	0	0	10	0	0
Beer per 100 hogsheads,	45	12	0	15	0	0	25	0	0
„ per 100 barrels,	22	14	8	10	8	0	20	0	0
Iron per ton,	1	14	0	0	12	0			
Coal and coke per ton,	1	6	0	† 0	12	0			
Exports									
Cotton and wool per 100 bales,	27	8	0	12	0	0	20	0	0
Grain per 100 bags,	11	0	0	3	0	0	10	0	0
Oil per 100 hogsheads,	45	12	0	12	0	0	20	0	0
Ghee per 100 dubbers,	11	0	0	8	0	0	18	0	0
Hides per 100 bales,	34	6	0	20	0	0	40	0	0

37 *Cost at Madras with a Harbour* —I believe the actual charges at Madras with a smooth water harbour would be less than at Kurrachee, as at the latter place the distance for lighterage is from two to three miles, whereas at Madras it would be about half a mile, and also the supply of skilled boatmen is more limited I have based the Madras charges on

	RS	A	P	
* Boat,	2	8	0	
Police Peon,	0	3	0	
Tarpaulin 4 as (occasional),	0	1	0	
	2	12	0	for 2 tons

† Exclusive of cooly hire for discharging from lighters

the tariff for Masula boats to the beach The charge to the pier is less by the amount of pier due, which equalizes the cost to the trader If the pier were enclosed in a harbour, ships would come alongside of it, and discharge direct, and so would save lightering altogether, thus giving to the pier an advantage equal to that given to the beach-landing system I am informed that some merchants have contracts with the Masula boatman at less than tariff rates, but, on the other hand, there are frequent extra rates, so that the tariff may be taken as a fair average

38 *Estimated amount of saving* —I believe that in assuming the saving in landing and shipping operations, and other consequent expenses, at *a rupee per ton of goods*, I am under the mark, but assuming this figure, and applying it to the lowest estimate given of the number of tons landed and shipped last year, viz , 2,75,000, we may rely upon a revenue derived from savings only of £27,500 This would pay interest at 4 per cent on £6,87,500 , at $4\frac{1}{2}$ per cent on £6,11,000, and at 5 per cent , on £5,50,000

39 *Estimated cost of Works* —A harbour made according to the accompanying plan would cost £5,65,000, including 10 per cent for contingencies, and 5 per cent for superintendence, and therefore seems to be within the resources of the trade of the port It is intended to be formed by piers running out from the shore 500 yards north and south respectively of the present screw-pile pier, enclosing a rectangular space of 1,000 yards long by 830 yards wide, or 170 acres, with a depth at low-water of from three to seven fathoms, and consequently available for European ships of all sizes, with a further space of a quarter of that area with a depth less than three fathoms, available for boats, lighters, and native craft

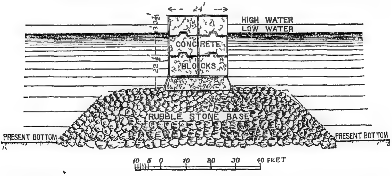
40 *Accommodation in Harbour* —Such a harbour would contain 13 ships of various sizes, from 4,000 to 700 tons, secured closely to fixed moorings, and able to swing, each in its own circle, clear of one another, also three ships alongside the pier, making 16 in all If the ships were more closely moored so as to swing clear of the next ship's mooring, but not of the entire circle she would describe in swinging, the number would be increased threefold This I am myself satisfied might be done with safety, since ships would be completely cut off from the strains and unequal disturbances of swell and current, and acted on only by wind But this is rather a matter for the consideration of the Nautical Authorities, and its determination is not urgent.

41 *Accommodation for maximum number not required* —Taking, how-

ever, 16 ships as the limit of the capacity of the harbour, I am informed that more than this number have been in the roads at one time on certain extraordinary occasions. I do not think, however, that it would be wise to incur the expense of providing for a repetition of such extraordinary contingencies. In the first place they are not likely to occur again unless as a consequence of a great increase of trade, because the effect of the increased employment of steamers is to facilitate the despatch of vessels from the port, and leave room for others, and this despatch will be further facilitated by the improved system of landing and shipping cargoes. In the second place, such a press would only occur during the most busy season, which is also the fine season, when ships would be as safe as they are now outside the harbour, but would have the advantage of the improved system of lightering to facilitate their despatch I therefore think that the additional expense which would be incurred by enlarging the harbour, so as to contain the maximum number of ships on record, would not produce any commensurate advantage

42 *Possible extension of accommodation*—But though I do not think it would be wise to incur expense in anticipation of increased trade, a policy which has often defeated its own object by crippling the immediate resources of the port, it is yet of the highest importance to be prepared for future extensions whenever increased trade or other circumstances may demand it This has been specially kept in view in designing both the plan of the harbour, and the details of construction

43 *Section of piers*—It will be seen by reference to the section of the piers appended, that they are proposed to be formed of a submerged



mound of rubble stone from the natural bottom to a depth of $22\frac{1}{2}$ feet

below low-water. Above this they will consist of two solid walls of concrete blocks laid close together so as to form one wall 24 feet wide This is very similar to the system followed in the case of a breakwater lately completed at Kurrachee

44 *Not in the first instance available as quay walls*—The two faces of such a pier are of such a character that ships might come alongside them, but it would be useless for them to do so, because the width of the pier, 24 feet, is insufficient for the purposes of a quay, and that on the weather side of the harbour would be exposed to the sea washing over it. To make the piers available as quays in the first instance would involve an additional cost, for which I do not think there would be an immediate equivalent

45 *Quays to be ultimately formed*—But I look forward to this as a second step, which in due time will be very advantageous. The pier as first constructed would be a mere sheltering breakwater When the trade requires more accommodation, I propose to form another similar sheltering breakwater at a distance of, say, 100 yards from the first, and parallel to it, as shown by the dotted lines on the plan The original pier would then be so far removed from the breaking sea, that ships might lie alongside without inconvenience, and the space between the two parallel piers being wholly or partially filled up, a wide quay would be formed, on which goods might be landed, and on which sheds and warehouses might be built, and thus greatly improved facilities for carrying on the business of the port would be provided. Such a quay wall would accommodate six or seven ships alongside of it, in addition to those swinging at moorings

46 *Further extension of works as may be required*—Should the extension of trade require still further accommodation, a second harbour similar to the first could be formed north or south, one side being already provided by the pier and quay of the first harbour For the present, however, it is enough to consider the merits or demerits of such a scheme as the present trade of the port is adequate to support

47 *Facility for Entrance and Exit of Ships*—I have already said that the principle of a closed harbour has been objected to on nautical grounds and the preference given to a detached breakwater, because ships can enter or quit more readily in any wind This argument would apply with still greater force in favour of the proposal to leave the roadstead in its present exposed state, for I fear there is no getting over the objection that

every obstacle to the entrance of waves is, to a certain extent, an obstacle to the passage of ships A ship, however, is more easily guided than a wave, and the objection, whatever it may be worth, becomes simply a question of the cost of employing steam-power It is, however, in my opinion, worth very little

48 *Objections urged by the Master Attendant*—In order to give the fullest prominence to the objections made, on nautical grounds, to the principle of a closed harbour, and especially to the special form I have adopted, I append a report by Mr Dalrymple, the Master Attendant of Madras, commenting on my first proposal, but in terms which are equally applicable to the present —

"I have the honor to acknowledge receipt of the papers specified in the margin, and to offer a few remarks on the project for the formation of a close harbour at Madras

"2 I shall first deal with Mr Parkes's letter, and his able "Note" in a nautical point of view, without presuming to touch on the engineering phase of the question

"3 In paragraph 11 of his ' Note," he is, I think, in error in assuming that at Kurrachee there is a heavier sea than at Madras In cyclones and gales of wind on this coast, the storm-waves cannot be surpassed.

"4 With reference to paragraph 21, I have only to state that, according to our experience and my own personal observation, every groyne which has been run out from the old sea wall, viz , the "DeHavilland's Bulwark," has carried the beach along with it, the longest groyne being about 400 feet in length, and consequently, as the shore has gained on the sea, the line of surf has moved out in proportion , and it is a question yet to be solved how long this same natural action of the elements will continue as similar works are pushed on seaward

"5 In regard to paragraph 23, I cannot see that the position of Port Said and its natural advantages added to the Suez Canal are at all analogous to those of Madras, which are simply *nil*, the attraction of the latter port being its cheapness and easiness of access, it being an open roadstead

"6 I concur with Captain Taylor in some of his opinions , yet my own opinion is this that, if we are to have a gigantic work for the protection of the shipping, a breakwater is the best It is thus far a certainty—the roadstead inside of it cannot silt up, and it will be a protection from the heavy break of the sea in a gale, when the wind is dead on shore, which is the time of peril to shipping

"7 The success of an enclosed harbour is supposed by numbers to be an impossibility ; at all events, it must be problematical

"8 I may also remark that during a gale, while a ship could run in under the lee of a breakwater for shelter from the *heavy sea*, she could not run into such a harbour as that proposed by Mr Parkes

"9 With reference to "Memorandum by the Chief Engineer" and his letter to the Head of the Marine Department, dated 5th April, 1873, No 128, I entirely agree with his views on the subject. If there is to be a harbour, it will be an imperative necessity to have the entrance protected by a breakwater , otherwise in a gale the

avy sea will roll in, and the ships in that confined space will grind each other to ieces, being in a much worse position than in an open roadstead

"10 I also entirely agree with the Chief Engineer regarding the nature and extent of our littoral currents, and in his judicious recommendation that Mr Parkes should side in Madras for a year or so to watch the currents, &c

"11 I may remark that these are at times so very strong, that the boatmen will ot float their boats unless the strong current flag is flying at the Master Attendant's agstaff, which entitles them to double hire I think this is pretty conclusive evidence that these currents exist

"12 With reference to the last paragraph of letter referred to, in the event of a arbour being constructed, tug steamers will be required to tow the ships in and out the harbour in fine weather, and it will depend on the space, which will be decided for the inside area of the harbour, as to the number of ships which can be berthed ongside the jetties and moored head and stern in the basin

"13 In conclusion, I may observe that, while I give the preference to a breakater as a more suitable work for this port than an enclosed harbour, and while I lly admit that it would alter greatly for the better the character of the roadstead, it yet to be borne in mind that, should any costly works be carried out, the interest the outlay must be provided for by an increase of rate of port dues, and in these ys of railway progress, and consequently increased facilities of communication to d from out ports, is it not to be expected that, in the circumstances, a considerable oportion of the Madras trade would too probably go elsewhere?"

49 *Remarks on the Master Attendant's Report* —With respect to paragraph 3 of the above report, my statement of the comparative force of the sea Kurrachee and at Madras was based on information obtained from perns well acquainted with both coasts, but the principles of my design are in way dependent upon its being correct (*see* paragraph 61 further on)

50 I have already entered fully into the subjects touched upon in ragraphs 4 and 5.

51 With regard to paragraphs 6 and 7, it is remarkable that, conlering the number of existing close harbours in all parts of the world, e success of the principle should be deemed problematical, while a heme, for which there is not a single precedent to be found in nature art,* should be pronounced certain of success

52 The opinion given in paragraph 8 will no doubt have its due ight. I will only state here that it is opposed to that of every nautiman with whom I have conversed on the subject, and that, as a matter fact, ships do continually enter harbours similar to that I have prosed in very heavy seas

NOTE —I cannot admit the resemblance suggested by Sir Arthur Cotton between a breakwater, ile long, and the formations known as "barrier reefs" generally extending for many miles

53 As to Mr Dalrymple's proposed breakwater to shelter the entrance, I do not myself think it would be either necessary or an improvement*, and this is the opinion of most of the competent persons with whom I have conversed on the subject, but it is a mere matter of detail, which may best be settled by actual trial of the effect of the entrance without a breakwater As to the ships in the harbour grinding one another to pieces, I need only refer to the plan which shows how they would be moored

54 With regard to paragraphs 10 and 11, I may remark that I do not question any of the *facts* given me by the Master Attendant and other competent persons as to the littoral currents I only maintain that they do not present any difficulty to the construction of a harbour, or to its use when constructed As to the nature of these currents, and as to their having no effect whatever on the bottom outside the line of surf, I believe Mr Dalrymple and myself are entirely agreed This being the case, it is difficult to see what object would be gained by my spending a year or so in watching currents, &c, which are already so familiarly known to Mr Dalrymple and others, and it is admitted have little or no bearing on the question

55 I entirely agree in the principle laid down in Mr Dalrymple's last paragraph, that an increase of port expenses would be detrimental to the trade of Madras, but I have shown that the plan I propose, can be carried out without any such increase

56 *Entrance to Harbour* —Having now stated the grounds on which I venture to think that the objections to the general principle of an enclosed harbour are untenable, I proceed to consider a point of detail which has been made the subject of some discussion I allude to the position and form of the entrance or entrances

57 *Comparative advantages of one and two Entrances* —The plan which I submit as being, in my opinion, on the whole the best, has an entrance 150 yards wide, facing east by south The alternative plan is to have two entrances at, or near the outer angles of the harbour The one undisputed advantage of this latter plan is, that vessels could enter or leave by one entrance or the other with any wind The one undisputed disadvantage is that, inasmuch as a sufficient space must be kept clear in the neighbourhood of each entrance for ships to bring up after entering

* See paragraphs 61 and 62 further on

the harbour, the space required for the second entrance would be lost as mooring ground

58 *For the Entrance and Exit of Steamers and Ships*.—These two considerations are inseparable from the very principles of the two systems, and the respective evils connot be averted by any arrangement of detail We can only endeavour to estimate their relative value The disadvantage of the double entrance is simply this—a sacrifice of one-fifth or one-sixth of the capacity of the harbour The disadvantage of the single entrance will be different for different classes of vessels For *steamers*, the most important class, it would be *nil* *Large sailing vessels* could enter or leave without steam power with the wind in 18 out of 32 points of the compass In the remaining 14 points either way, a steam tug would probably be required But it must be remembered that with an on-shore wind, a large outward-bound ship would probably take a tug to get an offing quite independent of the question of clearing the harbour, while to an inward-bound ship, with an off-shore wind, there would be at least smooth water and good anchorage till she could be towed in

59 *For Native Craft*.—*Native craft, outward-bound*, could certainly sail out of the entrance whenever they could beat off the shore, and *inward-bound*, with an off-shore wind, they could bring up, if unable to enter the harbour, on the more sheltered side, north or south, and either discharge there or warp in at leisure I, therefore, cannot estimate the disadvantage of having only one entrance as being of much practical importance to any class of vessel

60 *For protection from Seas with one Entrance*.—More importance has probably been attached to another objection, which, however, I cannot admit as undisputed, viz, the danger from heavy seas from the eastward rolling into the harbour Those who urge this objection are probably not fully aware of the effect produced upon such seas when they enter a harbour They are immediately dispersed, and the extent of reduction is not, as in the case of an open breakwater, a matter of speculation, but it is one of exact calculation * Captain Biden, the former Master Attendant, estimates the maximum height of wave at Madras at 10 feet Such a wave entering the harbour would be reduced to 1 foot 9 inches before it reached the piers or the beach A wave 15 feet high (the maximum measured at Kurrachee), would be reduced to 2 feet 7 inches—neither very formidable.

* Stevenson on Harbours.

61 *With two Entrances* —Whether the two entrances would admit more or less swell with an easterly sea would depend on their width and form If equally accessible to vessels as the eastern entrance, they would, I believe, together admit more sea, and the reductive power of the harbour would be less, as each wave would spread over only one right angle instead of two right angles

62 *Effect on Seas from different Directions* —With the north-east monsoon swell, the eastern and northern entrances would be about on a par, but the former would have more reductive power If the tranquility of the harbour were inversely proportioned to the duration and force of the wind to which the entrances are respectively exposed, the easterly one would have a marked advantage over either of the others separately, and of course in a far greater degree over the two together,* but the easterly seas are the heaviest and most dangerous, and go far to counterbalance this advantage On the whole, however, I am of opinion that the balance of advantage is on the side of the single entrance facing east by south

63 *Details of Execution—Granite* —I have now to offer a few explanations as to the details of the mode of carrying on the work The great bulk of the material required is of course stone I have visited St Thomas' Mount and Palaveram to the south, and the Red Hills, Avady, Umbatoor, and Seetapetty on the west of Madras In the former direction the material is granite, and might be brought in any quantity by the Carnatic Railway now under construction, but it is so exceedingly hard, that it would be very expensive to quarry, and would probable come out in blocks of inconveniently large size I, therefore, discard this source of supply

* *Abstract compiled from Observatory records*

Wind		1870	1871	1872
N by W —N, N by E —N N E, N E by N,	Duration Mean rate,	1,741 hours, 7 4 miles,	1,213 hours, 6 6 miles,	1,360 hours 7 35 miles
E by N —E, E by S —E S E, S E by E,	Duration, Mean rate,	1,124 hours, 5 7 miles,	1,192 hours, 5 7 miles,	1,215 hours 5 8 miles
S by E —S, S by W —S S W, S W by S,	Duration, Mean rate,	1,420 hours 7 6 miles,	1 493 hours, 7 85 miles,	1,339 hours. 8 4 miles

64. *Laterite* —At the other places the material is laterite, of which the best quality would be very suitable for those parts of the work where great hardness is not essential, such as the curved approaches to the piers, which I propose to carry over the shifting sand near the shore, as simple embankments of rubble stone, and for the rubble bases of the piers themselves The Breakwater Committee very wisely rejected the use of this material, as in their section it would be exposed to the destructive action of the waves, for which it is not sufficiently hard In my section it will not be so exposed, and with due care in selection it may be used with perfect confidence

65 *Conveyance by Railway* —A branch from the Madras Railway at Umbatoor, nine miles from Madras, running northward for about two miles, would cut through an ample supply of this material, which the Railway Company would bring to the very site of the works

66 *Trittany Granite for Concrete* —For the bulk of the concrete, I have estimated for a better material, granite from Trittany, fifty miles from Madras, but I think it not improbable that even for this purpose laterite would answer, and, if so, a saving on the estimate would be effected

67 *Beach Railway* —A line of railway would require to be laid along the beach for the conveyance of the stone to make the curved approach to the south pier, and for the concrete blocks for the superstructure of the pier itself, but the whole of the rubble stone for the bases of both piers would be placed in boats (probably steam hopper barges) at the north pier, so that after the curved approach was completed, the traffic along the beach railway would be very limited

68 *Concrete-mixing Station and Stacking Ground* —There appears to be no difficulty in a portion of the beach north of the Railway station being occupied by the necessary concrete-mixing establishment, and ground for making and stacking the blocks Branch railways would, of course, be laid for the conveyance of materials

69 *Time of Completion* —The first operation would, of course, be the formation of the curved approaches These might be commenced immediately, and while they are in progress, the necessary plant and machinery could be collected The actual building of the piers could be completed in three years, or, say four years from the time of the approaches being commenced

70. *Remarks on Estimate* —The estimate of £5,65,000 is, I consider,

a safe one, and is based on a fair allowance for the increase of ordinary rates, which generally accompanies the execution of so large a work. In the event, however, of the work being placed in the hands of any other Engineer, a new and entirely independent one should be framed by him, but I see no reason why it should exceed mine.

71. *Survey required.*—Before any works are commenced, it is most desirable that a new and detailed survey of the roadstead should be made, the soundings of which should be referred to a permanent mark on shore. The level of mean sea should also be accurately determined, and where the rise and fall of tide is so small, I think the mean sea-level would be a better datum than that of low water. The surveys on which I have based my calculations and drawn my plans are rather vague, and but for the extreme simplicity of the natural features of the coast, would have been insufficient. I believe, however, that neither design nor estimate can be materially affected by any possible corrections that may be made, but an exact record of the existing state of things is imperative before works which may effect a change in them are commenced.

72. *Conclusion.*—In conclusion, I have only once more to express my acknowledgments of the uniform courtesy with which I have been received by every one with whom I have come in contact in the prosecution of my inquiries and the readiness with which every information and assistance has been afforded to me. If I mention no names, it is because I should not know where to stop.

W. P.

APPENDIX

Cyclones and other Storms at Madras recorded at the Government Observatory

1787, *11th November* Centre *North* of Madras	Wind at noon on 10th, N Midnight N N W 11th, sunrise, N W Noon N W After sunset, violent and veering all round the compass 12th, sun-rise, S S W Noon S 13th, sunrise, calm
1788, *7th May* Centre *North* of Madras	Sunrise N W Noon N W Midnight N W 8th, sunrise, W Noon W Midnight S S W 9th, sunrise, S S W Noon S S E Midnight, calm
1797, *27th October* Centre at Madras	Began from northward, veered to N E, blew with uncommon violence three hours, about noon suddenly shifted to south, and was almost as violent as before
1807, *10th December*, Centre *South* of Madras	Began from N, veered to Southward of E, and slackened gradually
1811, *2nd May* Probably central at Madras	Began from N, blew equally strongly from E S E and S, but details not given Not felt 40 miles from Madras
1818, *24th October* Central at Madras	Began northerly, then a lull of half an hour Then from south with greater fury The most violent storm then on record
1820, *30th March* Centre *North* of Madras	Commenced from N E, veered to N, N W and S W, but at last quarter gradually slackened More violent to northward than at Madras
1820, *9th May* Centre *North* of Madras	Commenced at N W, shifted to W Worse than storm of October, 1818
1827, *7th May*	Strong wind from S E.
1827, *8th May*	Early morning strong gale from N E
1827, *9th* May Centre *North* of Madras	From sunrise strong gusts from E to S till 10 A M when nearly ceased At sunset blew from W N W and during the night a gale from N W Subsided

in the morning of 10th This storm longer in duration, but not so heavy as preceding ones

1830, *2nd December* Centre *South* of Madras — A stormy day, but at Cuddalore, 100 miles south of Madras, a very violent storm

1836 *30th October* Central at Madras — Very violent First from north, then a lull of 30 minutes, then with increased fury from south Much more severe than those of 1818 and 1820 as shown by barometer

1841, *16th May* Centre *North* of Madras — A gale of extraordinary violence At 9 A M N N E, 10 A M to 5 P M north Then for an hour varying from N E to N W At 6 20 P M approaching a hurricane from N, at 7 to 7 30 from W to N 7 45 south-westerly, a violent gale 8 to 9, S W to N W and shifting even to S, approaching a hurricane Thence subsided, remaining at S to S W calm after 7 A M on 17th

1843, *22nd May* Centre *North* of Madras — N to N W for 24 hours previous From 7 A M till 1 P M continually shifting from N W to S W and back

1846, *20th October* Centre *North* of Madras — Began at 11 A M, wind W N W, then at 1 P M due W, remained between W and W S W till 8 P M, force increasing to 8 lbs * Then back to W rising to 18 lbs Then rapidly veered round the compass by E and S till at 7 A M on 21st, direction S S W, force 7½ lbs Then gradually fell, direction being S by W

1846, *25th November* Centre *South* of Madras — At 5 P M N E force 5 lbs At 7 30, E by N pressure 26 lbs, then instrument broke. At 7 A M calm due S

1847, *13th October* Pure Northerly gale, not cyclonic — During the day wind N. W and N., for ¼ hour, at 8 45 P M changed to E of N then remained due N for the rest of the gale having a maximum force of 12 lbs at 6 A M Subsided at 3 P M returning N W

* From 1846 to 1850, the force of the wind is given in lbs on a square foot Subsequently its velocity is given in miles per hour

1848, 1*st November* Light centre *South* of Madras	Began before sunrise, N N W under 5 lbs At 2 P M N N E At 7 30 N E $6\frac{1}{2}$ lbs, at $4\frac{1}{2}$ A M on 2nd wind E and dropped to $1\frac{1}{2}$ lbs
1850, 21*th May* Centre *South* of Madras	At 10 A M light at E by N increasing till 1 30 P M, E N E, maximum at 2 P M E S E (12 lbs) at 4 P M dropped to 5 lbs S E by S
1851, 4th *May* Centre *North* of Madras	At 11 P M (3rd) 5 lbs N W by N At 3 30 A M increasing in force from W At 5 30 A M maximum force $17\frac{1}{2}$ lbs, direction W At 9 A M dropped to 10 lbs S W, diminishing at S S W Calm at S
1856, 20*th November* Centre *North* of Madras	Began at 4 P M, direction N N E (5 lbs) At 9 30 P M N E (8 lbs) steady till 2 A M 21st (12 lbs) Then veered northward, maximum force 17 lbs At 4 30 A M N by E Then back to W of N, dropped to 5 lbs by 9 A M, direction N W
1864, 18*th November* Light centre *South* of Madras	At 3 P M N by W (25 miles) steady till 9 P M Then veered to N E by N and N E, by 9 45 Continued to increase till at 2 P M it was 28 miles per hour, and it dropped from thence as wind veered to the south
1865, 26*th November* Centre *South* of Madras	Began on 26th at 8 A M from N E by N, speed 25 miles, then gradually increasing all day till at 9 P M it was N E by E, with speed of 43 miles Then decreased as it veered to S E by 6 A M, and thence to south, where it dropped
1872, 1*st May* Centre *South* of Madras	Wind northerly for two days previously Blew steadily but with gradually increasing force from N to N N E till midnight Then increased rapidly up to 8 A M, being then 53 miles, direction N E By 9 30 veered to E Then gradually working towards the south, dropping to 14 miles at 8 P M, and then remaining steady in direction and force from S to S S E for several hours

[*Note by Editor*.—In connection with the above Report, the following Extract from "Thornton's Indian Public Works," in regard to this projected harbour, will be found interesting :—

"The harbour is intended to serve less as one of refuge than as a gigantic dock where cargoes may be landed or shipped in smooth water instead of in the midst of surf, and by means of ordinary lighters instead of Massulah boats, an immense deal of damage being thus prevented, and much time and therefore money saved. It is calculated that altogether the expense of landing and shipping will be reduced by at least 2s. per ton at which rate the reduction on 275,000 tons, the assumed aggregate of imports and exports, will amount to 27,500*l*., and it is further calculated that, in order to defray the annual expenses of the harbour when finished, inclusive of interest at 4 per cent on its cost, a charge of very little more than half per cent on 6,000,000*l*., the supposed value of the aggregate imports and exports will suffice. Not improbably it may be found impracticable to subject the entire trade to this tax, which could not reasonably be levied in respect of vessels that did not make use of the harbour, and, in that case, any deficiency in the expected receipts from port dues might have to be made good at imperial expense. But the Madras Harbour scheme does not depend for justification on the prospect it holds out of direct pecuniary remunerativeness. The risks which, in my humble judgment, may reasonably occasion some uneasiness are, first, that of the harbour (which as seems to be admitted on all hands, must inevitably silt up sooner or later) becoming choked much sooner than its advocates expect, and, secondly, that through an opening of 150 yards, facing due east, dangerously heavy seas may gain admittance, in heavy weather, much farther within the harbour than is commonly anticipated. If, however, apprehensions on these scores should be proved by experience to be groundless, and if the harbour be really found to answer its purpose, its construction may then be entitled to be regarded as an enterprise in which, though it might have ruined private undertakers, public money has been profitably expended. For, irrespectively of their inestimable national value as guarantees against loss of life and property by shipwreck, the services rendered by good harbours are of the same nature, though different in degree, as those obtained from good roads or good railways. By facilitating access to market they increase the value of produce, raw as well as manufactured, and therefore that of land, and consequently, in a country like India, where the Government is landlord-general, increase too, indirectly, if not directly, the revenue of the State."

The first stone of the new Harbour Works was laid by the Prince of Wales, on the 11th December, 1875.]

Notes on the Proposed Harbour for Madras on the Plan designed by Mr Parkes—its defects pointed out, and remedies suggested By ROBT J BALDREY, ESQ [*Vide* Plate XVII]

Preface—I am fully alive to the difficulty of my self-imposed task, and conscious of my inability to give suitable expression to my thoughts and ideas on a subject, the importance of which demands an abler pen than mine to depict But as nothing has been done to warn the public of the impending evils which, I believe and feel assured, will result on the completion of the Close Harbour about to be formed on a design by Mr Parkes, and as the matter is of vital importance to every citizen, especially householders, whose property, in the event of failure, cannot, like that of merchants and traders, be removed to a more favored Port or City, I should consider myself culpable were I any longer reticent from a feeling of diffidence as to my powers to handle so difficult a subject, and repugnance to give publicity to my opinions

I should indeed be the last to oppose an undertaking which, if successful, would undoubtedly enhance the value of the several landed properties which I hold in Madras,—such a proceeding would be counter to my own interest,—so it is not probable I would publish this protest, were I not convinced that there are reasonable grounds for doing so Being interested in the project, I was induced to study the plan of Harbour, and not being altogether without local experience after a residence of more than 30 years, and not entirely devoid of knowledge on Engineering matters after a service of about 22 years under the Madras Railway Company and Public Works Department, I was enabled to form an opinion which, I regret to say, is not at all favorable to the plan, for in every delineation of it I fail to read anything but disaster and ruin! to our good old City This being my conviction, I consider it nothing but my duty to submit the matter to my fellow-citizens, and should these statements be considered worthy their attention, it is left to them to pursue whatever course they may consider necessary to avert the evils threatened Feeling that possibly a wrong view may be taken by me, I submitted my opinions to the judgement of gentlemen whose knowledge on nautical matters and local experience relating to the peculiarities of this coast is unquestionable, and the result was that they concurred with

me on every point put forward in this paper Feeling myself thus supported in my views, I submit them with greater confidence to the public

I may state, in conclusion, that I was informed by good authority, that experienced Mariners frequenting this coast, declare, that rather than risk their vessels being ground to pieces in a harbour which provides no shelter from the force of the wind during a hurricane, they would clear out and take their chance in the open sea when warned of the approach of one

From the latter statement, together with others made to me, I would infer that by publishing these papers, I am but expressing a general opinion regarding the close Harbour proposed for Madras

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Prior to the execution of a gigantic project, such as the harbour scheme for Madras, the success or failure of which would act either beneficially or prejudicially to the Port, it is considered highly desirable, with reference to the proposed project, to obtain all the local experience possible by inviting the residents, whose interest it is to aid, to contribute their mite of information to the general stock By such a procedure, much light will be thrown on the subject, and from quarters where little was expected to be elicited

This precaution is yet the more necessary, when able and scientific men hold opinions of a conflicting nature regarding the proposed project, and judging from the various reports on the subject, the question as to the practicability of carrying out a work which would provide suitable accommodation and shelter to shipping in the Madras Roads appears to be a case in point, and it would be unreasonable to ignore any information which may help to attain the desideratum coveted, simply because it did not emanate from a source considered to be orthodox Any particulars, therefore, bearing on the subject, should not be discarded, however humble the source from which they may be drawn, but be impartially weighed and investigated, and thus the path leading to a successful termination will be cleared of all doubts and difficulties

In the event of Mr Parkes' plan being carried out, the evils apprehended are particularized as follows —

1st Inundation of the Town

2nd Unsuitability and consequent failure as to the object for which it is built

3rd Production of sickness

4th Faulty construction and imminent destruction.

I shall therefore divide my subject under the following heads —

Physical, Nautical, Sanitary and Construction,—concluding with my suggestions as to how the defects may be remedied

I shall now proceed to analyze the several heads of my subject, which does not pretend to anything more than an earnest appeal to that rather rare gift, vulgarly designated "sound common sense"

1st Physical.—The features of the Coast of Madras are familiar to my readers, and it will be plain to all, that on such a bold, straight, and low-lying coast with strong littoral currents, any solid pier or arm projecting a considerable distance into the sea at right angles to the line of coast will naturally arrest the progress of the littoral currents, and the obstructed body of water will rise considerably at the point of interception, especially during the periods of strong littoral currents produced by storms during the North-East and South-West monsoons, the direction of either of these winds will force the waves into the north or south angle caused by the projection of the pier from the coast, and drive the waters literally into a corner and cause them to overleap the low bulwark and rush into the town, carrying everything before them, and the disaster which lately befell Masulipatam will be re-enacted

From its lowness, Madras is subject at any time to such a catastrophe, and any measure having a tendency to precipitate its occurrence, should be avoided I may here quote from Talboy Wheeler's "Madras in the Olden Time," page 128, extract from original records —"The sea having "for about ten days past encroached upon this town, and we hoping as it "is usual, that it would retreat again of itself, forebore any remedies to "keep it off, but now that instead of its losing, mightily gains ground up-"on us, and that without a speedy course be taken, the town will run an "apparent hazard of being swallowed up, for it has undermined even to the "very wall, and so deep that it has eaten away below the very foundation "of the town—and the great bulwark next to the sea side, without a speedy "and timely prevention, will certainly in a day or two more yield to its "violence it is therefore ordered forthwith that the drum be beat to call "all coolies, carpenters, smiths, peons and all other workmen, and that "sufficient materials be provided, that they work day and night to endea-"vour to put a stop to its fury, for without effectual means be used in "such an eminent danger and exigency, the Town, Garrison, and our own "lives, considering all the foregoing circumstances, must needs be very "hazardous and insecure." Then from a "General Letter" from England —

"We take notice of the great inundation that endangered our Town and "Fort, and we would have you endeavour to prevent such future acci-"dents * * * * by raising new works as a security to their lives, houses, "wives and children, and of all that belongs" to them I have myself witnessed in ordinary weather a wave break over De Haviland's bulwark or sea wall, and sweep its way past the base of the lighthouse Such being the case under ordinary circumstances, with the natural and unaltered line of coast, what may not be expected should an obstructing medium be interposed to the natural course of an impetuous current

Mr Parkes' Project offers just such an obstruction the two arms or piers which he proposes to project several thousands of feet into the sea at right angles to the line of coast present an opposing body to the storm currents in their natural and straight course along the shore It is, to say the least of it, very unwise to court danger, and that reason alone should be a sufficient objection against the adoption of any plan which is likely to cause loss to life and property, especially when its ostensible object is to effect the very reverse —as far as I have been able to ascertain, the possibility of inundating the Town from the effects of solid piers, projecting into the sea, has not been as yet considered by the authorities

The storm currents on this coast are prodigious in force and rapidity I am well assured of this, for I have been several times an eye-witness to their effects I have watched the hardy Madras boatman (than whom as a class I have not seen more venturesome and expert swimmers) whilst endeavouring to convey a line to a vessel about to be stranded on the coast, on one occasion somewhere between the Public Works' Workshop and the Ice House, when he was borne rapidly away in a few minutes by the strong current, notwithstanding all his eel-like endeavours to gain the shore, which he only reached somewhere between the bar and Cupid's bow, a distance of about a mile and a half To get to the vessel, he had to proceed a considerable distance south in order to drop down on her, which he did, for he had admirably calculated his distance, and had scarcely time to cast the line on board when he was swept past the vessel The simple circumstance only serves to show that much is to be feared from any abrupt projection from the line of coast It may be argued that inundation of the town may be effectually guarded against by erecting a sea wall of sufficient height, to a considerable distance on each side of the harbour to protect the low-lying districts, but is this a contingency

that is allowed for in the estimate? if not, the great additional cost would, I consider, be a serious objection, especially when a design precluding any fear of inundation can be provided.

Such an objection cannot be charged against a work like my proposed breakwater, for, being detached from the shore, the water cannot be pent up to cause inundation to the town, for it admits of a free passage to the currents between the work and the beach; from a detached work like this, shoaling cannot be apprehended: this is the opinion of Sir Arthur Cotton and others (*vide* Mr Parkes' Report), for the simple reason that the currents along the coast will drive out or scour the sand from between the outwork and the beach, especially if the outwork or breakwater lying parallel to the coast is not of very considerable length, the reductive power on the waves and current flowing into passage between breakwater and shore being proportionate to the length of passage with the squares of its relative width.

On the other hand, it is admitted by all authorities, Mr Parkes himself included, (*vide* his Report, paras 14 and 15,) that piers or groynes extending from the shore will arrest the drift sand; the proposed harbour, therefore, being nothing more than two piers or groynes which, after running out a considerable distance from the beach into the sea, converge and almost meet; the space between their extremities forming the entrance to the enclosed area intended to shelter vessels: these piers will undoubtedly arrest the sand, but not to the extent supposed by Mr Parkes, viz., a triangular space two sides of which will be formed by the pier and shore, for such a mass of sand will not be deposited, owing to the scooping action of the strong littoral current sweeping the sands along with it round the pier wall of harbour, which on its passage to meet the shore again will deposit the greater portion in the mouth of the harbour, choking it up; this is instanced in several cases where piers have been used. Cressy describing Newhaven and the piers forming it, says "this harbour, *like others on the south coast*, is greatly affected by the accumulation of beach and shingle which cannot be effectually scoured or washed away by any means yet attempted, notwithstanding the great indraught and eddy tide which set towards the mouth, the average rise of spring-tide at the harbour's mouth being 19 to 20 feet, and of neaps about 14 to 15 feet." Such being the case with harbours, possessing the great natural advantage of a constant tidal scour, what can be expected in the case of a close harbour at Madras, where there is only an occasional high

water of about 3 feet? Looking nearer home, I shall conclude my remarks regarding the effects produced by groynes or solid pier-walls by quoting from a report to Government by a local authority "I have," he says, "only to state that according to our experience and my own personal observation, every groyne which has been run out from the old sea "wall, viz, De Haviland's Bulwark, has carried the beach along with it, "the longest groyne being 400 feet in length, and consequently as the "shore has gained on the sea, the line of surf has moved out in proportion, "and it is a question yet to be solved, how long this same natural action "of the elements will continue as similar works are pushed on seawards"

The above statement is by a marine authority whose experience extended over a period of as many years as did that of Mr Parkes in days

With all the natural advantages and the protection which the indented coast of Great Britain affords for the formation of close harbours, it is a recorded fact that numbers of far greater capacity than that proposed for Madras suffer severely from shoaling, so much so, that a port on account of it has been abandoned, and the space once occupied by the harbour is now turned over by the plough-share, for agricultural purposes, yet it is disallowed by Mr Parkes, except at a very distant date, and therefore considered no element for consideration, that the close harbour for Madras will be affected by shoaling, notwithstanding all the facilities afforded by the bold, straight, unsheltered sweep of coast (entirely dissimilar to any of those of Great Britain) to the passage of littoral currents, bearing, on their unimpeded course, their burthens of drift sand to be deposited as they speed on in the first cavity or indented space which presents itself along the line of coast

Mr Parkes fixes the period of the shoaling of his harbour at the remote date of 180 years I fail to understand how he could have based his calculations, as he states in his report that he has done, on the amount of sand deposited between the groynes during a season, for it is an undoubted fact that the sand is constantly warped round the head of each groyne by the action of the currents (the very fact of the filling in of the centre and those spaces between groynes furthest from the direction of the current proves this), then the sand deposited, say between the first two groynes, will displace an equivalent or be itself borne over to the second space, and so on to the last, to be washed out on to the other side of the beach, only to be brought back after a time by the alternate motion of the current It is this very principle of action which takes place

in the process of harbour shoaling, and one which I have tried to explain. This alternative warping of the sand over the pier heads of any close harbour connected with the shore at Madras will effectually close up, if not fill it. Mr. Parkes further remarks, that the spaces between the groynes were not filled, as if he considered that process of filling was not completed. I have only to say, neither will they ever be, even after the expiration of a thousand years, if the groynes preserve their form so long, with littoral currents, for the scooping or corroding action of the waves will wear away the sand from the one or the other side of the groynes according to the direction of the current, leaving on the lee side a space unoccupied by sand; the head of each groyne or pier will preserve a clean appearance, for the sand is washed round it constantly, and no deposit at the extremity is allowed to take place.

It will be seen by the foregoing, that after a certain accumulation of sand has taken place, the quantity of which need not be sufficient to fill in a rectangular space between the groynes, the surplus sand or that portion which the groyne, not being of sufficient length, could not arrest, is constantly borne backwards and forwards over the heads of the groynes by alternating currents. Such being the case, the deposit *during the season* on which Mr. Parkes based his calculation, would have been far greater, within the same given time, had the groynes been of greater length so as to retain or catch the surplus travelling sand; this, no doubt, would inevitably have been the case. From the foregoing, I consider that I have shown the fallacy of the data on which Mr. Parkes has based his computation, and is it not now possible, that the evil of shoaling (which would be a death-blow to the object for which the work is to be executed) be much nearer to our doors than he anticipates? This is not only possible, but very probable, for there are no currents and surf on the face of the globe more industrious in conveying their sandy treasures to and fro, than those on the Madras coast.

To still further satisfy myself as to the fact of the sand being borne round the head of the groynes, I have caused the surface sea water near the head of a groyne to be caught in a vessel, and found on settlement that there was a considerable quantity of sand at the bottom; the amount of silt thus borne round the groynes of course would depend on the agitation of the waters at the time.

It is therefore a matter for serious consideration whether so large a sum as 56½ lakhs of rupees should be expended on a work the plan of

which, as far as I have shown, promises nothing more than disaster by inundation and the defeat of its object by shoaling

I shall now proceed to view the subject from a nautical point

2nd Nautical—Spots sheltered by nature have, as a rule, been selected for harbours, but the Madras roads do not afford the slightest protection from the very winds that are most destructive to her shipping Even with the most ordinary high winds, danger, it is, apprehended, will be experienced by vessels attempting an entrance into a harbour of the form proposed by Mr Parkes, who in his report states, that Mr Robertson, Harbour Engineer for India, is of opinion that vessels can enter and quit more readily from behind a breakwater than through the one entrance of a harbour This appears to be the general opinion of nautical men frequenting this coast, and who are aware of the heavy seas to which our very unsheltered roadstead is exposed

I shall quote from several statements made by experienced mariners Captain J D Gaby, of steam ship "*Khiva*," says "The force of the "sea against the pier heads" (of the proposed harbour) "with any winds "from the Eastward, and the eddies caused thereby, a vessel would pro- "bably lose her steerage way, and unless the engines of the steamer, or the "tug towing the sailing ship are very sharply worked, she would most "likely get damaged against the pier, or else run into a ship lying at the "buoys before she would recover herself"

From Captain J H Atkinson, Superintendent, British India Steam Navigation Company, Calcutta "The currents would at times run "strongly across the harbour mouth, and good judgment with local "knowledge would be required to avoid being set on to either pier head, "as having to bring up in a comparatively short distance, the slow "rate of speed necessarily maintained would give time for considerable "drift, the current acting on the length of the vessel"* * * "That the "advantage to be derived from two mouths is, that they would probably "afford amore certain exit from the port, should the action of a cyclone "storm wave cause damages to the sea wall, and by that or other means "drift dèbris which might close entrance"

From Captain T Black, Superintendent, Peninsular and Oriental Steam Navigation Company, Southampton "The majority of those I have con- "sulted, and with whom I myself coincide, think that a long breakwater "would be more suitable of the two, (enclosed harbour and breakwater,) "the idea being fostered more by the nautical than the commercial aspect

"of the question * * * * Vessels arriving or putting to sea would also be "able to do so with greater facility behind a breakwater than going in or "out of a close harbour To the mail steamer of this Company, we think "a close harbour, such as Mr Parkes advocates, would necessitate a certain "amount of risk while entering at night, small of course if there were "light and the water smooth, but considerable with a strong wind and a "high sea, and the difficulty of bringing up a long steamer in the compa- "ratively small area which Mr Parkes' plan shows, would be great, sup- "posing that a moderate number of ships were already at anchor inside, and "the steamer were obliged to enter with a good way on her to secure steer- "age * * * I think great weight should be attached to Captain Dalrym- "ple's remarks, that during a gale a ship could run in under the lee of a "breakwater for shelter from the heavy sea, while she could not run into "such a harbour as that proposed by Mr Parkes, and that in such a har- "bour the heavy sea would roll in, and the ships in the confined space grind "themselves to pieces, being in a much worse position than in an open road- "stead In point of fact, Captain Dalrymple, Master Attendant at Madras "evidently thinks that a close harbour *at Madras* would be most dangerous "in cases when shelter would be most required, and I personally am greatly "inclined to coincide with him" Mr Parkes himself acknowledges in para 31 of his Report "I have no hesitation in saying that a roadstead exposed "to the most prevalent and strongest winds, even irrespective of the direc- "tion of the heaviest seas, cannot be considered to be effectually sheltered"

The foregoing statements need no comment from me, they speak for themselves, and are to the point No harbour in Madras with one entrance, and that facing East by South, will be accessible during the preponderating high winds from the North-east

3rd *Sanitary*.—Under this head the effects which will be produced by a close harbour at Madras will now be considered.

It is always thought to be a matter of the greatest importance to adopt necessary measures for the effectual scouring or washing out of harbours, to rid them not only of silt, but of the accumulated filth from shipping, &c The indraught and ebby tides (which are considerable in most harbours, those of Rye harbour being 23 feet spring tide and 14 feet neap) and tidal rivers, are taken full advantage of to effect this great desideratum, for without such means a harbour would be soon rendered useless and would further prove a source of pestilence,—in fact, the plague-spot of the Port. Subsequent to my consideration of this material point, my

views were corroborated by the following statement by Captain J H Taylor, R N R —"The landing place at Colombo, though having the "advantage of the weak scour, is pestiferous from the mere decomposition of the spilt grain cargoes and general accumulation of matter" Captain W Stewart, commanding steam ship "*Indus*," writes —"There is one "point to which no reference is made, viz, what will be the sanitary state "of such a closed harbour? I suppose, if necessary, some opening could "be left to ensure all accumulation of impurities being carried off by pre- "vailing currents"

This important point appears to be entirely omitted in Mr Parkes' plan, and, as it is argued by him when describing the reductive power of his harbour, that a wave 10 feet in height outside the harbour will be reduced to a wavelet 1 foot 9 inches on its entrance into it, no scour then can be obtained from such a source, and the only effect which it is expected to produce will be the deposition of everything abominable on the shore within the harbour, and in the event of the harbour's mouth being closed up with sand, the effects of stagnation, together with the accumulated impurities, will render it under a tropical sun, in reality the plague-spot of *Madras*, to remove which extraordinary measures, at an enormous cost, will have to be resorted to Serious inconvenience will not at first be experienced, but after a few years the accumulation of filth, owing to the small rise and fall of the sea, will soon make itself apparent, and discerned by more senses than one This state of things would be highly objectionable, when it is considered that the harbour will be contiguous to the most thickly-inhabited part of the city—Black Town

Those who resided in the Fort some few years ago, will not easily forget the overwhelming stench which evolved from a ship, with a cargo of rice, that was stranded somewhat North of the Fort, it was simply so abominable, that it at once awoke the proper authorities to unwonted energy, and the decomposing grain was bundled helter skelter and committed to the "oozy deep," and if I remember rightly, one or two of the coolies died whilst clearing the vessel Residents who were present on the above occasion will be able to form some idea of the nuisance described by Captain Taylor regarding the landing place at Colombo I have frequently noticed grain washed along the shore which probably was lost during transmission to and from shipping, this, if not cleared away by the current but enclosed instead in an almost stagnant pool, would, with other matter, in the space of a few years, convert the harbour into a

large cesspool It is evident from the foregoing, that it is very necessary to so design a harbour as to allow of its being effectually scoured by the means which nature offers, such can be effected, and I shall endeavour to explain in its proper place, how it can be carried out without additional cost

The "Silvery Cooum," although having the advantage of being flushed out by freshes once or twice during the year, yet exhales effluvia at times, during the dry season, the most noxious and life-poisoning What will then be the condition of a close harbour after the lapse of a few years without any such advantage? The cost of diverting the sewers from emptying themselves into the close harbour is also another item which will necessitate a considerable outlay, this can also be avoided by an arrangement which I shall suggest The objection to a close harbour for Madras, from a sanitary point of view, is serious, and should be sufficient to arrest the attention of the authorities, for what advantage would it be, supposing even that the harbour afforded all the security to the shipping which is expected from such a work, if the inhabitants of a thickly populated city, and particularly those located in the leading Mercantile houses in Madras, situated on the North Beach, were subjected, by their close proximity, to the baneful effects of impure atmosphere generated by the nuisance described

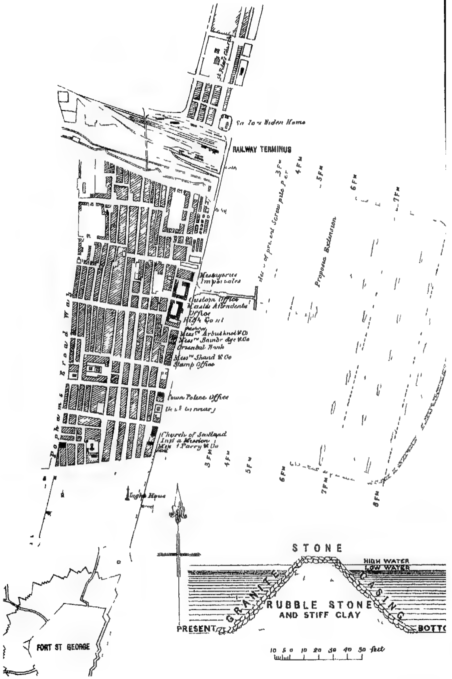
4th *Construction* —From long observation of the progressive settlement of the boulders of stone used in the construction of the groynes on the beach, and from the gradual disappearance of immense quantities thrown into the roadstead by Captain, now Sir Arthur Cotton, with a view to the formation of a breakwater,* I am led to the conclusion that stones loosely precipitated into the sea, with no cementing agency to bind or connect the stone or rubble into a compact mass, will, in the course of time, be scattered by ground swells and currents, and individually gravitate and be lost in the sand Such being the inference I have drawn, I am of opinion that the loose rubble intended to be deposited to form a base, on which it is proposed to erect the concrete-block wall of Mr Parkes' harbour, will effect anything but a solid foundation for the intended superstructure This is the more forcibly conveyed to the mind, when it is considered that the pier or sea-wall proposed for Madras, is precisely on the same principle of construction as that just completed for the harbour at Kurrachee, and which has already given way

* This mound of stone was many years ago so near to the surface, that it was considered dangerous to shipping, and buoys had to be moored about it to indicate the spot It is said that very little of the once great heap is at present to be seen

PLAN OF THE TOWN, AND ROADSTEAD OF MADRAS

(Showing the Harbour proposed by Mr R Baldrey)

[DATED 3RD NOVEMBER 1875]



Remedies proposed —In preparing a design for a suitable harbour for Madras, I have kept in view the objections to both the close harbour project and that of the breakwater, and endeavoured to keep clear of the defects or doubtful points of each, selecting the unobjectionable or good characteristics which both possess, and which, if combined, would, I feel confident, afford suitable shelter to the shipping in the Madras Roads, and thus avoid all the dangers apprehended from the adoption of either the close harbour by Mr Parkes, or the breakwater

In the preparation of my plan, I have avoided the introduction of any construction having its origin at, and projecting from, the shore, in order that sand may not be conducted or borne by the currents from the beach along its extent into the harbour and thus shoal it up, and further that there will be no possibility of inundating the town, by avoiding the interposition of an arm from the shore, extending several thousands of feet into the sea Taking advantage of the currents and adapting them to that end, I have secured a sufficient scour or circulation of the water to keep the harbour free from impurities and consequent danger to public health The openings which will admit the necessary scour, will at the same time provide a double entrance to the harbour, a point considered to be of great importance by nautical men By this arrangement, easy ingress and egress is also secured without any loss in mooring space, as in the case of Mr Parkes' arrangement consequent on position of entrance

The form of harbour which I suggest, will, by shutting out the sea on the North, East and South sides, protect shipping from the heavy seas from the North-east, East, and South-east directions, well known to be most destructive to shipping,—provision is also made to protect the shipping from strong winds In rough weather it will afford ample mooring space for twenty ships, and in fair weather double that number, whereas in that of Mr Parkes' plan, only thirteen at any time can be accommodated, this is done without any additional cost, for the length of the sea-wall which I propose is only 8,000 feet, whilst that of Mr Parkes is, including the shore extensions, 10,000 feet If it is proposed to accommodate only thirteen ships as in Mr Parkes' plan, a considerable reduction will be effected, and that too on the more expensive principle of construction which he has adopted

Reporting the capacity of his harbour, Mr Parkes says "If the ships "were more closely moored, so as to swing clear of the next ship's

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In the preparation of my plan, I have avoided the introduction of any construction having its origin at, and projecting from, the shore, in order that sand may not be conducted or borne by the currents from the beach along its extent into the harbour and thus shoal it up, and further that there will be no possibility of inundating the town, by avoiding the interposition of an arm from the shore, extending several thousands of feet into the sea Taking advantage of the currents and adapting them to that end, I have secured a sufficient scour or circulation of the water to keep the harbour free from impurities and consequent danger to public health The openings which will admit the necessary scour, will at the same time provide a double entrance to the harbour, a point considered to be of great importance by nautical men By this arrangement, easy ingress and egress is also secured without any loss in mooring space, as in the case of Mr Parkes' arrangement consequent on position of entrance

The form of harbour which I suggest, will, by shutting out the sea on the North, East and South sides, protect shipping from the heavy seas from the North-east, East, and South-east directions, well known to be most destructive to shipping,—provision is also made to protect the shipping from strong winds In rough weather it will afford ample mooring space for twenty ships, and in fair weather double that number, whereas in that of Mr Parkes' plan, only thirteen at any time can be accommodated, this is done without any additional cost, for the length of the sea-wall which I propose is only 8,000 feet, whilst that of Mr Parkes is, including the shore extensions, 10,000 feet If it is proposed to accommodate only thirteen ships as in Mr Parkes' plan, a considerable reduction will be effected, and that too on the more expensive principle of construction which he has adopted

Reporting the capacity of his harbour, Mr Parkes says "If the ships "were more closely moored, so as to swing clear of the next ships

"mooring, but not of the entire circle she would describe in swinging, "the number would be increased three fold," a calculation which will make the capacity of the suggested form of harbour 120 vessels in fair, and 60 in foul, weather

The cheapest cementing body I can think of to bind the rubble, is good stiff clay, which can be obtained in abundance, and at an exceedingly low cost The non-percolating and adhesive qualities of clay are well known This mixed with the rubble in a proportion that would be sufficient to fill in the interstices of the stones, and, in the course of deposition, held together in large coarse sacks, would thus deposited, form a mass, that will, I feel assured, become the more compact by settlement, a result which cannot be expected under similar circumstances from a concrete structure

The average dimensions of sea-wall proposed by me are as follows —

Perpendicular, 50 feet, which will carry it 8 feet above high sea level

Base, 120 feet, top or platform, 24 feet

These measurements will give a natural slope of 45 degrees on each side

The core will be of laterite rubble, one-fourth of the bulk of which will be composed of stiff clay to fill up the interstices and bind the work together

The core thus formed, will be preserved from the corrosive action of waves and currents by a casing of granite boulders, 6 feet in thickness over the whole mass

Such a massive structure would present a more effectual bulwark to the buffetings of storm waves, than would be offered by the more expensive but less massive one, proposed to be carried out by means of concrete blocks

The wall proposed by me will be 8,000 feet in length, so the total bulk, according to the foregoing section, will be 1,026,296 cubic yards, the component parts of which are to be

Rubble,	611,556 cubic yards, at Rs	2 8 0,*	Rs	15,28,890
Clay,	203,852 ,, ,, ,,	0-8 0,	,,	1,01,926
Granite boulders,	280,888 ,, ,, ,,	4-0 0,	,,	11,23,552
Total bulk,	1,096,296 cubic yards		Total Rs	27,54,368

leaving a balance sum of Rs 28,95,632 out of the sum sanctioned for Mr.

* The rate at which the harbour works is at present supplied with laterite rubble from the quarries at Ambatoor is, inclusive of Railway charges, about Rs 2 to 2 8 per cubic yard deposited into the sea

Parkes' harbour, to be expended in providing shelter to the shipping from winds, extension of present screw pile pier, plant, coarse sacks, establishment, contingencies, &c

The piles intended for the extension of the present screw pile pier can be employed during construction of the sea-wall for the purposes of a jetty to convey material from the beach opposite the Railway station at Royapooram to the northern extremity of the proposed sea-wall, from which point the work can be commenced

Further details regarding labor need not here be entered into, nor do they require description as they are well understood

The objections to a close harbour for Madras are serious in the extreme, and at best to use the words of a local Marine authority —"The success of "an enclosed harbour for Madras is supposed by numbers to be an impossi-"bility, at all events it must be problematical" As for the breakwater, unless it extended a considerable distance parallel to the line of coast, (which could only be effected at an enormous cost), it would be of no practical use, for the vessels would be driven from their moorings by storm currents of a north-easterly or south westerly direction This is obviated by the large area enclosed by my form of harbour, the force of a storm current would be dissipated by having to spread over such a considerable extent of sheltered space, and a wholesome scour will be the favorable result This reductive power will be most advantageous for boats, for they may ply at any season, if there is even any necessity for it, or as it can be seen by reference to the plan, the pier is proposed to be extended to the most favorable point to enable shipping to lay to for the purposes of loading and unloading

I consulted a Government Marine Authority as to the distance vessels could approach the shore with safety, he considered that a vessel could approach to about 500 feet off the pier, this is a distance of 1,500 feet from the shore, but I have allowed 3,400 feet from the shore to the terminal points of the proposed sea-wall, thus giving ample space for egress and ingress to vessels in any weather This distance from the shore is the more favorable, as there is no shifting sand beyond this point, the bed of the sea there being clay (*Vide* statement of Government Diver, Breakwater Committee's Report)

Summary —The form of harbour I propose will then avoid

Inundation of the Town.

Shoaling

Additional ill-health to the city

Disaster to vessels from insufficient entrance and from want of shelter from strong winds and exposure to heavy seas from east

Advantages to be derived by the adoption of the form of harbour proposed by me

Mooring space—Considerably more area is provided for mooring vessels, probably all that will ever be required, and at less cost than that proposed by Mr Parkes

Scour—A sufficient scour or washing out of the harbour is obtained by the passage of the currents through the two openings intended for entrances

Two entrances—An advantage considered of great importance by nautical men

Protection to shipping—Great storm waves from the East run dead on shore, and are considered the most dangerous to shipping, it has been therefore a matter for particular consideration to provide against such a contingency, which is effected by entirely shutting out the heavy seas from that direction

Ready conversion into a close harbour should there be any necessity for it—This can at any time be effected by continuing and joining the North and South walls with the shore, whereas in the event of Mr Parkes' harbour proving a failure, the possibility of converting it into any other form will be precluded by the extension of his walls from the shore

Cheapness—A harbour of far less cost than that proposed by Mr Parkes can be carried out, even if constructed with the expensive materials he proposes, if accommodation equivalent to that provided by him is only required

Future extension—Should this ever be required, it could be carried out by constructing only two sides, either to the North or South of the proposed harbour

In conclusion, I trust I have given an intelligible form to my ideas on this subject, and by cautiously steering clear of the strong objections to a Breakwater or Close Harbour as unadapted to the requirements and peculiarities of this coast and combining the good points in each, I have realised a form of harbour suitable for Madras

R J B

RITHERDON ROAD,
EGMORE, 23rd *Nov*, 1875

BULL'S DREDGERS.

FIG. 1

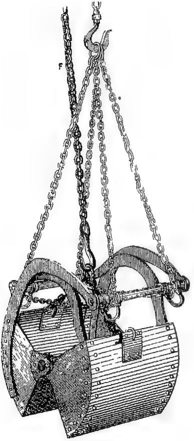
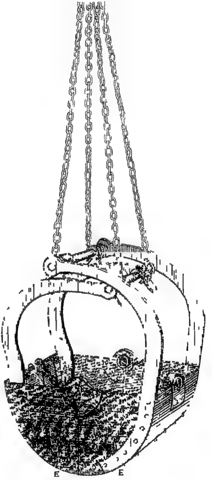


FIG 2



No CLXXXVIII

IMPROVED METHOD OF WORKING BULL'S DREDGERS

[*Vide* Plate XVIII]

BY W. BULL, ESQ, *Resident Engineer, Oudh and Rohilkhand Railway*

Description of an Improved Method of working the larger sizes of Bull's Dredgers

HITHERTO considerable difficulty has been felt in handling the larger sizes of this machine when full This can be entirely obviated by having a short supplementary chain attached to the dredger, as shown in *Plate* XVIII

Where a double action steam crane is available, as is often the case in harbour and other works, the dredger should be lowered by means of the second chain above alluded to, which would take the place of the key in keeping the jaws of the machine open, the chain attached to the arms being kept slack On reaching the bottom, the dredger can be quickly filled by alternately putting a strain on to the two chains, sufficient to partly close and open the machine without lifting it When filled it should be raised in the ordinary way, the lowering chain being hauled up at the same time, but kept slack The dredger having been brought over the spot where it is desired to empty it, the lowering chain is tightened and the raising one slackened It then immediately empties itself, and is ready for lowering again without the necessity for applying manual labour in any way

If a double action crane be not available, the dredger may be simply emptied in the same way, by having a chain with a hook fixed in the proper position, but not attached to the dredger When it is brought

up full, by fixing this hook into the ring in the middle of the short supplementary chain and slackening the chain attached to the arms, the same result as before described will be realized In this case the key must be fixed when emptied

The short chain attached to the upper edge of the two halves of the dredger may be dispensed with, by having a double end to the second chain with a hook on each to fix into a hole on each half of the machine

By the arrangement thus described, machines to bring up a ton of sand or mud at each operation may be worked with ease It is of course quite distinct from the machine itself, and can be fitted at pleasure

W B

No CLXXXIX

CONTINUOUS UNIFORM BEAMS

[*Vide* Plates XIX XX and XXI]

BY CAPT. ALLAN CUNNINGHAM, R E, *Hon Fell. of King's Coll, Lond*

Preface —The treatment of the Problem of Continuous Uniform Beams here adopted is different to that hitherto employed in English Treatises The whole Theory is here* made to depend on the THEOREM OF THREE MOMENTS, from which the Moments of the "Re-action Couples", and thence the "Shear-Re-actions" are readily found This reduces the question to a form almost the same as that of a simply "Supported Beam" Integral Calculus is required only to establish this Theorem —with its aid, Cases of Continuous Uniform Beams are soluble by elementary Algebra and Geometry In preparing this Paper, the object has been kept in view of presenting all the final Results in a form *of immediate use to the practical Engineer* Accordingly Tables have been prepared exhibiting (in an algebraic form) the values of the Integrals occurring in this Paper for all the most useful cases of practice

[The usual procedure has been to investigate *only the Case of uniform load* and to integrate the equation of the Elastic Curve *specially, for each Case* of Beam of two spans, three spans, &c, and thence to seek the "Total Re actions" of the Supports as the *primary* unknown quantities This method is open to the objections —

1° No one investigation is intelligible to a Student not familiar with Integral Calculus

2° It is not susceptible of generalization

3° The choice of the "Total Re actions" as the *primary* unknown quantities is unsuitable, and greatly complicates the question]

Notation The Notation used is uniform with that of the Author's Manual† of Applied Mechanics

1 **Continuous Beams.**—A single Beam covering several Spans and resting on several Supports is styled a CONTINUOUS BEAM or GIRDER In rigid material, the Pressures on the several Supports (or Re-action of

* This Method has been adopted from Vol III "of the Cours de Mécanique Appliquée" of the "Ecole Imperiale des Ponts et Chaussées" by M Bresse, 1865 The whole of the Results, however, have been prepared specially for this Paper

† This Paper is embodied in Part II of the Manual just being published

those Supports) would be strictly indeterminate when there are *more than two Supports*, because there are only two equations of equilibrium between them, viz,

Sum of Re-actions = Total Load, . (1*a*)

Sum of Moments of the Re-actions about any axis, } = { Moment of the Loads about same axis, } (1*b*)

In elastic material, however, the determination of these Re-actions is a perfectly definite Problem for material whose elastic properties are known. The solution depends, therefore, ultimately on the fundamental law of elasticity (Hooke's law) from which the equation of the Elastic Curve is deduced.

The continuity of the Beam enables the weight of the Spans adjacent to any particular Span to supply Re-actions at the two vertical end sections of the latter which tend to reduce the Transverse Strain (Deflexion), and therefore also the (longitudinal) stress-intensity which a given Load would cause on that Span if discontinuous.

This is of course a great advantage in Construction: the investigation of the Stress in a Continuous Beam is therefore of considerable importance.

It is easy to see in a general way that the effect of the continuity is to throw the Elastic Curve into a sinuous form, usually convex upwards over the Supports, and concave upwards near the centre of each span, these portions being separated by points of inflexion, of which there are commonly two in each Span, so that each Span is as a rule in the condition of a SUPPORTED BEAM between the inflexions resting on two CANTILEVERS. It is easy also to see, that under particular conditions of Load, two or more points of inflexion may coalesce, and one or more of the usual curvatures be effaced. As a general Rule, however, it is clear that

1° A segment *concave upwards* between two inflexions is precisely in condition of a SUPPORTED BEAM under its actual Load, } (2*a*)

2° A segment *convex upwards* from an inflexion to a point where the Elastic Curve is horizontal is precisely in condition of a CANTILEVER under its actual Load, together with a concentrated Load at its free end (the inflexion) equal to the Shearing Force at that point. Two such CANTILEVERS necessarily occur together, separated at the horizontal point, which is equivalent to the fixed end of a Cantilever, . } (2*b*)

2. Shear-Re-actions, Re-action Couples, Total Re-actions.—Consider any one span (A′A″) of a Continuous Beam. It clearly

differs from a similar, similarly loaded Supported Beam solely by reason of the continuity at the Supports (A′, A″). The material of the adjacent Spans is thus enabled to apply certain Stresses at the ends A′, A″ of the Span A′A″, which affect the shape of its Elastic Curve.

By elementary Statics, the whole of the External Forces acting on the Beam A′A″ at its ends A′, A″ are equivalent to a certain (vertical) Resultant Force applied at A′, together with a certain Couple, and to a certain (vertical) Resultant Force applied at A″, together with a certain Couple, the Resultant Forces and Couples being of course all in the "plane* of solicitation."

The Resultant-Forces and Couples are clearly of the nature of Re-actions—as affecting the span A′A″ under consideration, and the two Resultant-Forces are clearly the Shearing Forces at the ends of the Span A′A″. For these reasons it is convenient to style them the SHEAR-RE-ACTIONS, and RE-ACTION-COUPLES† of the Span A′A″.

[Observe that the SHEAR-RE-ACTIONS are the complete Re-actions applied to the Span A′A″ at its ends, but are only partial (not Total) Re-actions of the Supports A′, A″, *see* Art. 12.]

It is convenient to use the following notation:—

R′, R″ the Shear-Re-actions at A′, A″.

M′, M″ the Moments of the Re-action-Couples at A′, A″.

F the Shearing Force } at any point whose abscissa is x', or x''
M the Bending Moment } (measured from A′ or A″, respectively.)

R', R'', F, M the corresponding values of the similar quantities in the span A′A″, if *discontinuous*,—

By the above notation it is clear that—

"The Resultant effect on the span A′A″ of the continuity is simply the application of *additional* external Forces and Couples at the ends, viz.,— $(R' - \mathit{R}')$ and M′ at A′, $(R'' - \mathit{R}'')$ and M″ at A″," (3)

[In using these quantities, care must of course be taken to apply them with the proper algebraic signs.]

Great use will be made of this principle in the sequel.

It is clear also by Elementary Statics that—

$$(R' + R'') = \mathit{R}' + \mathit{R}'' = \Sigma_0^l w, \text{ (or Total Load on A′A″)} \quad (4),$$

also, taking Moments round A′, A″ in turn,

$$M'' = M' + (R' - \mathit{R}')l, \quad M' = M'' + (R'' - \mathit{R}'')l, \quad (5)$$

3. Shearing Force.—By the very definition of the term it is clear that

* "Plane of solicitation." This term is applied to the Load plane or longitudinal plane of symmetry of the Load, which should also be a plane of symmetry of the Beam.

† The term "Stress Couple" has also been applied to these Couples.

$$\mathrm{F} = \mathrm{R}' - \Sigma_0^{x'}\,\mathrm{w} = -\,(\mathrm{R}'' - \Sigma_0^{x''}\,\mathrm{w}), \quad .. \quad (6),$$
$$= \mathrm{R}' - R' + F = -\,\mathrm{R}'' + R'' + F, \quad (7)$$

[It is easily seen that these expressions are equivalent]

Again, let F', F'' be the Shearing Forces *at the ends* A′, A″ proper to the span A′A″

As already explained (Art 2), these are equal to the Shear-Re-actions at A′, A″, hence by the convention* as to the sign of a "Shearing Force"

$$\mathrm{F}' = \mathrm{R}',\ \mathrm{F}'' = -\,\mathrm{R}'', \quad . \quad (8)$$

4 Bending Moment.—By the very definition it is clear that at any section x',

$$\mathrm{M} = \mathrm{M}' + (\mathrm{R}' - R')\ x' + M, \quad . \quad . \quad . \quad (9)$$

Eliminating $(\mathrm{R}' - R')$ from (5), (9),

$$l\,\mathrm{M} - x'\,\mathrm{M}'' = (l - x')\,\mathrm{M}' + l\,M,$$

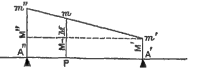
$$\text{whence, } \mathrm{M} = \frac{x'}{l}\ \mathrm{M}'' + \frac{x''}{l}\ \mathrm{M}' + M, \quad . \quad . \quad (10),$$

a remarkably simple expression for M, which admits of simple interpretation, for it is equivalent to

$$\mathrm{M} = \left\{\mathrm{M}' + \frac{x'}{l}\,(\mathrm{M}'' - \mathrm{M}')\right\} + M, \quad . \quad . \quad (11),$$

now, if in *Fig* 1, A′ m, A″ m″, be plotted upwards representing M′, M″ on a scale of moments, then the length Pm clearly represents the quantity

Fig 1



$$\left\{\mathrm{M}' + \frac{x'}{l}\,(\mathrm{M}'' - \mathrm{M}')\right\}$$

so that the straight line $m'\ m''$ is the graphic representation of the excess of M over M, *i e*, of the difference of actual Bending Moment (M), and what it would be if the span were *discontinuous* (M)

It is easy to see that the very steps by which the following relation is usually established (*see* any Work on Applied Mechanics) in the case of "Supported Beams" are really applicable to all Beams, so that in the present case also,

$$\frac{\Delta\,\mathrm{M}}{\Delta\,x} = \mathrm{F}, \text{ or } \frac{d\,\mathrm{M}}{dx} = \mathrm{F}, \quad . \quad ... \quad (12).$$

5 Maximum Bending Moment—The Bending Moment in a Continuous Beam has *usually* one positive maximum in each Span, and one negative maximum at each Support, or more strictly one maximum between every two inflexions, viz,

* Of the pair of Shearing Forces at any section, (one on either side,) that on the right of the section will be termed the "Shearing Force", that on the left the "Shearing Resistance" they are denoted by F, $\mathcal{F}$, respectively.

(1) One positive maximum in each segment of the Elastic Curve which is concave upwards (like a Supported Beam), (13a)

(2) One negative maximum in each segment of the Elastic Curve which is convex upwards (like a Cantilever), (13b)

These maximum values can *generally* be found by solving the equation

$$\frac{d\,\mathrm{M}}{d\,x} = 0, \text{ or } \mathrm{F} = 0, \qquad \ldots \quad (14),$$

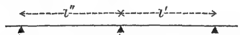
which gives the abscissa of the section required. The value of the maximum Bending Moment is then at once found by substituting that value of the abscissa in the general expressions (9, 10, 11) for M The values thus found are usually positive maxima, and are then conveniently denoted by* M_0

But the Bending Moment is also *commonly* (not always) a negative maximum at each Support because the segments of the Beam on either side of each Support are *usually* in condition of CANTILEVERS Its value at the Supports is, of course, always the same as the moment of the Reaction-Couple (M′ or M″)

6 Theorem of Three Moments—BRESSE'S THEOREM†—This important Theorem reduces the whole Theory of CONTINUOUS UNIFORM BEAMS to a form solvible by Elementary Algebra, by furnishing an *algebraic* relation between the Re-action-Couples at three successive Supports

[The investigation cannot be effected without use of Integral Calculus The Result, however, (21,) is all that is required *in practice* Tables of the values of the Integrals in this Result, and in those derived from it are provided herewith, so that the Result itself can be used at once by the practical Engineer without requiring any knowledge of integration]

Fig 2.



$\mathrm{A}_1, \mathrm{A}_2, \mathrm{A}_3$ are any three successive Supports

$\mathrm{M}_1, \mathrm{M}_2, \mathrm{M}_3$ are the Moments of the Re action-Couples at $\mathrm{A}_1, \mathrm{A}_2, \mathrm{A}_3$

M the Bending Moment at any section whose abscissa is x

A_2 the origin, a horizontal line through A_2, the x *axis*

x', x, x'' are abscissæ measured from $\mathrm{A}_1, \mathrm{A}_2, \mathrm{A}_3$, respectively

v_1, v_2, v_3, the ordinates of the Elastic Curve at $\mathrm{A}_1, \mathrm{A}_2, \mathrm{A}_3$, *after the straining action is complete*

r_1, r_2, r_3 the tangents of the inclinations of the Elastic Curve at $\mathrm{A}_1, \mathrm{A}_2, \mathrm{A}_3$

l', l'' the lengths of the spans, $\mathrm{A}_1\,\mathrm{A}_2$, $\mathrm{A}_2\,\mathrm{A}_3$ $\quad c =$ semi span.

The equation of the Elastic Curve *applicable to any Beam whatever*, gives—

$$\mathrm{EI}\ \frac{d^2v}{dx^2} = \mathrm{M}$$

* This notation is intended to show that they usually occur *near the middle* ($\xi = 0$) of each span

† This Theorem is due to M Bresse, and is published in Vol III of his "Cours de Mécanique Appliquée"

Integrating and observing that $\frac{dv}{dx} = \tau$, when $x = 0$, and that in a Uniform Beam (to which case this investigation is limited) I is constant,

$$\mathrm{EI}\ \left(\frac{dv}{dx} - \tau_2\right) = \int_0^x \mathrm{M}\ dx \qquad (15)$$

Integrating again, and observing that $v = v_1$, when $x = l'$, and $= v_2$ when $x = 0$,

$$\mathrm{EI}\ \left(v_1 - v_2 - \tau_2 l'\right) = \int_0^{l'} \int_0^x \mathrm{M}\ dx\ dx$$

$$= l' \int_0^{l'} \mathrm{M}\ dx - \int_0^{l'} x \frac{d}{dx} \int_0^x \mathrm{M}\ dx\ dx$$

$$= \int_0^{l'} (l' - x)\ \mathrm{M}\ dx \qquad (16)$$

$$= \int_0^{l'} x'\ \mathrm{M}\ \ dx', \qquad (17)$$

[This last form is obtained by changing the origin to A_1, which be it observed, *leaves M unchanged*]

Introducing the general value of M from Result (11), the l, M′, M″, of which become l', M_1, M_2—

$$\mathrm{EI}\ (v_1 - v_2 - \tau_2 l') = \int_0^{l'} x' \left\{ \mathrm{M}_1 + \frac{x'}{l'} (\mathrm{M}_2 - \mathrm{M}_1) + M \right\} dx'$$

$$= \tfrac{1}{2}\, l'^2\, \mathrm{M}_1 + \tfrac{1}{3}\, l'^2 (\mathrm{M}_2 - \mathrm{M}_1) + \int_0^{l'} x'\, M\, dx' \quad , \qquad (18)$$

$$= \tfrac{1}{6}\, l'^2\ \mathrm{M}_1 + \tfrac{1}{3}\, l'^2\, \mathrm{M}_2 + \left[\frac{x'^2}{2} M\right]_0^{l'} - \tfrac{1}{2} \int_0^{l'} x'^2 \frac{dM}{dx'}\ dx'$$

$$= \tfrac{1}{6}\, l'^2\ \mathrm{M}_1 - \tfrac{1}{3}\, l'^2\, \mathrm{M}_2 - \tfrac{1}{2} \int_0^{l'} x'^2\ \ F\, dx' \qquad (19a)$$

[This last Result is obtained by observing that after the integration by parts M vanishes at both limits ($x' = 0$, or l'), and that as in Eq (12), $dM - dx' = F$]

Applying a similar process to the other Span $\mathrm{A}_2\ \mathrm{A}_3$,

$$\mathrm{EI}\ (v_3 - v_2 + \tau_2 l'') = \tfrac{1}{6}\, l''^2\ \ \mathrm{M}_3 + \tfrac{1}{3}\, l''^2\ \ \mathrm{M}_2 - \tfrac{1}{2} \int_0^{l''} x''^2\ \ F\, dx'' \quad (19b)$$

the abscissæ (x'') being measured from A_3

Writing the abbreviations

$$\mathrm{K}' = \int_0^{l'} \frac{x'^2}{l'}\ \ F\, dx',\ \ \mathrm{K}'' = \int_0^{l''} \frac{x''^2}{l''}\ \ F\, dx'' \qquad . (20),$$

and eliminating τ_2 from Equations (19a, b) there results,

$$\mathrm{M}_1 l' + 2\,\mathrm{M}_2 (l' + l'') + \mathrm{M}_3 l'' = 3\,(\mathrm{K}' + \mathrm{K}'') + 6\,\mathrm{EI} \left\{ \frac{v_1}{l'} - v_2 \left(\frac{1}{l'} + \frac{1}{l''}\right) + \frac{v_3}{l''} \right\}, (21)$$

This Result (21) is the important THEOREM OF THREE MOMENTS it gives a simple linear relation between the Moments of the Re-action-Couples *at any three successive Supports* (of a Uniform Beam), two easily calculable integrals (K′, K″),—(*see* Art 8 for a Table of their values),—and the levels (v_1, v_2, v_3, which are supposed given quantities) of those Supports after the strain is complete

The importance of this Result consists in its being a *linear function* of only three of the sought quantities (M_1, M_2, M_3, &c) Thus in a Continuous Beam of n spans its repeated application gives a system of $(n - 1)$ simple equations, each involving only three of the sought Moments, (which are of course $(n + 1)$ in number)

Hence, if any two of those Moments can be determined *à priori*, the rest can be found by solution of the above $(n - 1)$ simple equations

7 THEOREM OF THREE MOMENTS FOR RIGID SUPPORTS —The most simple, and practically most important, case is that in which the level of the 'neutral surface' is maintained *constant over the Supports*—(by their rigidity)—in which case all the quantities v_1, v_2, v_3, &c, vanish, so that the Equation of Three Moments (21) becomes

$$\mathrm{M}_1\, l' + 2\, \mathrm{M}_2\, (l' + l'') + \mathrm{M}_3\, l'' = 3\, (\mathrm{K}' + \mathrm{K}'') \qquad (22)$$

8 *Reduction of the integrals*—The values of the integrals (K', K″) are recorded below for the most useful cases in practice, so that by help of these results, the important Theorem of Three Moments (21, 22) *may be used at once without requiring any knowledge of integration*

The following Table contains the values of the quantity —

$$\mathrm{K} = \int_0^l \frac{x^2}{l}\ F\ dx, \qquad (23),$$

for the most useful simple cases of load distribution It will suffice to change l in the values of K below to l', l'' to give K', K″ as required Also it is obvious—from the meaning of integration—that for any combination of Loads for which the values of K are K_1, K_2, &c, for each separate Load,

$$\mathrm{K} = \mathrm{K}_1 + \mathrm{K}_2 + \mathrm{K}_3 + \&c = \Sigma\, \mathrm{K}_n \qquad (24),$$

or, The value of K for a combination of Loads, $=$ The sum of the values of K for the partial Loads, (24A)

LOAD [Span AB $= l$, A the outer Support, B the middle Support]	Value of $\mathrm{K} = \int_0^l \frac{x^2}{l} F\, dx$ [Origin always at A, the outer Support]
Single Load ($-$ W) at distance x_1 from A, x_2 from B, $x_1 + x_2 = l$	$\frac{1}{6}\,\mathrm{W}\,\frac{x_1}{l}\,(x_1^2 - l^2)$, or $\frac{1}{6}\,\mathrm{W}\,\frac{x_2}{l}\,(x_2 - l)\,(2l - x_2)$
Single Load ($-$ W) at centre of span	$-\frac{1}{16}\,\mathrm{W}\,l^2$, or $-\frac{1}{2}\,\mathrm{W}\,c^2$
Equal Loads ($-$ W) distant x_1 from the ends A, B	$\mathrm{W}\,x_1\,(x_1 - l)$
Uniform load ($-\,w$) over whole span	$-\frac{1}{12}\,w l^3$, or $-\frac{2}{3}\,w\,c^3$
Uniform load ($-\,w$) over segment AP, AP $= x_1$, (BP $= x_2$ unloaded), $x_1 + x_2 = l$	$\frac{1}{12}\,w\,\frac{x_1^2}{l}\,(x_1^2 - 2l)$, or $\frac{1}{12}\,w\,\frac{(l - x_2)^2}{l}\,(x_1^2 - 2\,l x_1 - l^2)$
Uniform load ($-\,w$) over segment BP BP $= x_2$, (AP $= x_1$ unloaded)	$-\frac{1}{12}\,w\,\frac{(l^2 - x_1^2)^2}{l}$, or $-\frac{1}{12}\,w\,\frac{x_2^2}{l}\,(2l - x_2)^2$
$(n - 1)$ equidistant equal Loads ($-$ W) cutting the span (l) into n equal segments	$-\mathrm{W}\,\frac{n^2 - 1}{12\,n}\,l^2$, or $-\mathrm{W}\,\frac{n^2 - 1}{3n}\,c^2$

CAUTION In using this Table, observe that the origin A is always *at the outer* Support (i e, A_1 for span $\mathrm{A}_1\,\mathrm{A}_2$, and A_3 for span $\mathrm{A}_3\,\mathrm{A}_2$), and B at the middle Support (i e, A_2 in set of three $\mathrm{A}_1\,\mathrm{A}_2\,\mathrm{A}_3$), so that the distance $x_1 = $ AP of the Tabular Results, is always measured from outer Support (A_1 or A_3)

Observing that x_1, x_2 are both necessarily $< l$, it is obvious that all the above values of K are *negative*

It would not be difficult to show from the form of the integral (23), that this is always the case, whence it follows that

"the quantity $(K' + K'')$ is always negative," (25)

and therefore in general Eq 22 shows that in *case of rigid Supports*,

"Of the Re action-Couples at any three successive Supports at least one is negative", (26)

9 Uniform Load Clapeyron's Theorem —This is in practice the most important case of the general Theorem, and is in fact the only one usually given in Text-books Taking the values of the integrals (K', K'') from the Table Art 8, and writing, w', w'' = load-intensities per length-unit in spans l', l'', the general Result (22) becomes for this particular Case (with rigid Supports),

$$M_1 l' + 2 M_2 (l' + l'') + M_3 l'' = -\tfrac{1}{4} w' l'^3 - \tfrac{1}{4} w'' l''^3 \quad .. (27)$$

This particular form of the general Theorem of Three Moments is known as "Clapeyron's Theorem".

10 *Theorem of Three Moments applicable only to Supported Uniform Beams* —The formation of the final Result (21) by eliminating r_2 from the two Equations (19*a*, *b*) involves of course that r_2 should be the same in both Equations, *i e*, that the Elastic Curves of the two adjacent spans l', l'' should have *a common tangent* at the common Support This involves the physical condition, that the two Spans should be *in no way fixed or constrained*, at their common Support, (except of course by the mutual constraint of their continuity), *i. e*, that the Beam be *simply supported at the Common Support*

The formation of the system of $(n - 1)$ equations above-mentioned, is therefore legitimate only when the Beam is *simply supported* at all the Supports over which it is continuous there is of course no restriction hereby as to the mode of Support at the ends

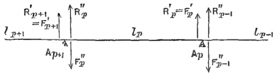
The integration, moreover, with I taken as constant clearly *restricts the Theorem* to Beams in which I is constant throughout the Beam, the only important practical instance of which is that of a Uniform Beam

11. Shear-Re-actions —When the Re-action-Couples have been found, the Shear-Re-actions are easily found as follows:—

Let A_1, A_2, A_3, .	A_{n+1}	be the	$(n + 1)$ Supports numbered from right.
R_1, R_2, R_3.	R_{n+1}	,,	$(n + 1)$ Total Re-actions, ,,
M_1, M_2, M_3 ...	M_{n+1}	,,	$(n + 1)$ Moments of Re-action Couples.
l_1, l_2, l_3	l_n	,,	n Spans ,, ,,

R'_p, R''_p be the Shear-Re-actions at right and left of p^{th} Span (l_p)
F'_p, F''_p be the Shearing-Forces at " " "
$\mathcal{R}'_p$, $\mathcal{R}''_p$ be the Re-actions at right and left of p^{th} Span (l_p), *if discontinuous*

Fig 3



Then, by Eq (5), $M_{p+1} = M_p + (R'_p - \mathcal{R}'_p)\, l_p$, . (28)

$$M_p = M_{p+1} + (R''_p - \mathcal{R}''_p)\, l_p \quad (29)$$

$$\text{whence } R'_p = \mathcal{R}'_p + \frac{M_{p+1} - M_p}{l_p} \quad \ldots \quad (30)$$

$$R''_p = \mathcal{R}''_p + \frac{M_p - M_{p+1}}{l_p} \quad \ldots \quad (31)$$

Thus the two Shear-Re-actions R'_p, R''_p at the ends of any span A_p A_{p+1} may be at once found when the Moments (M_p, M_{p+1}) of the Re-action-Couples at its ends are known Moreover,

$R'_p + R''_p = \mathcal{R}'_p + \mathcal{R}''_p = \Sigma_0^{l_p} w =$ Total load on the Span, (32), from which equation either is still more easily found when the other is known

12 Total Re-actions—By what precedes it will be understood that any particular Support A_p yields the partial Shear-Re-actions R''_{p-1} to the Span on its right (of which it is the left Support), and R'_p to the Span on its left (of which it is the right Support) Thus—

Total Re-action at p^{th} Support $R_p = R''_{p-1} + R'_p$ . . (33)

$$= - F''_{p-1} + F'_p, \quad (34)$$

Substituting from Eq (28*a*, *b*), remembering to change p into $(p-1)$ in the substitution for R''_{p-1}

$$R_p = \mathcal{R}''_{p-1} + \mathcal{R}'_p + \frac{M_{p-1} - M_p}{l_{p-1}} + \frac{M_{p+1} - M_p}{l_p} \ldots \quad (35)$$

Case of end Supports (A_1, A_{n+1})—By above notation, it is clear that

$$R_1 \doteq R'_1 = F'_1 = \mathcal{R}'_1 + \frac{M_2 - M_1}{l_1} \quad \ldots \quad (36)$$

$$R_{n+1} = R''_n = - F''_n = \mathcal{R}''_n + \frac{M_n - M_{n+1}}{l_n}, \quad \ldots (37).$$

It is clear also, that if W_p = Total Load on p^{th} span,

$$\left.\begin{array}{r} \text{Sum of Total Re-actions} = \text{Sum of Total Loads,} \\ \text{or } \Sigma_{p=1}^{p=n\pm1} R_p = \Sigma_{p=1}^{p=n\pm1} W_p \end{array}\right\} \quad (38)$$

When n of the Total Re-actions have been determined, this equation gives usually the easiest way of determining the remaining one

13 *Case of Continuous Beam simply supported at the two ends* —This is the most ordinary case in practice the Beam *simply resting on the End Abutments* without being there fixed

The End Supports are, therefore, unable to supply any Re-action-Couples, so that the Moments at the two extreme ends (A_1, A_{n+1}) are necessarily zero,

$$i\ e,\ M_1 = 0,\ M_{n+1} = 0 \quad (39),$$

and those at the $(n-1)$ intermediate Supports are, therefore, all completely determinable by the system of $(n-1)$ Equations of the "Three Moments"

14 Curvature.—The fundamental equation of Curvature

$$\frac{1}{\rho} = \frac{M}{EI} \quad (40),$$

applicable to all Beams shows that —

1° "In Continuous Beams the Curvature $(1 - \rho)$ is of the same sign as the Bending Moment (M), and is therefore,
2° "Concave upwards (like a Supported Beam) when M is positive,
3° "Concave downwards (like a Cantilever) when M is negative,
4° "Vanishes when M is zero, so that the Curvature changes sign, passing through a point of inflexion when M is zero", (41)

These Results justify the general statements of Art 1

15. Elastic Curve —It may be shown by a process, similar to that of Art 6, that—using the notation of that article—if A_1, A_2, A_3 be any three successive Supports, the equation of the Elastic Curve is, with origin at A_2,—
In Span $A_1 A_2$,

$$\left.\begin{array}{l} EI\left\{l'(v - v_1) - x(v_1 - v_2)\right\} = \dfrac{x^3 - l'^2 x}{6} M_1 + \dfrac{3l'x^2 - x^3 - 2l'^2 x}{6} M_2 \\ \quad + \dfrac{l'x}{2} K' + l'\displaystyle\int_0^x \int_0^x M\, dx^2, \end{array}\right\} \quad (42a)$$

In Span $A_2 A_3$,

$$\left.\begin{array}{l} EI\left\{l''(v - v_3) - x(v_3 - v_2)\right\} = \dfrac{x^3 - l''^2 x}{6} M_3 + \dfrac{3l''x^2 - x^3 - 2l''^2 x}{6} M_2 + \\ \quad \dfrac{l''x}{2} K'' + l''\displaystyle\int_0^x \int_0^x M\, dx^2) \quad \ldots\ldots \end{array}\right\} \quad (42b)$$

The levels of the Supports v_1, v_2, v_3 are supposed to be given in most applications in practice, it is usual to assume them zero

The values of the integral are given in Table below, those of K', K″ were given in Art 8 thus when M_1, M_2, M_3 have been calculated, the Elastic Curve can be plotted by calculating its ordinates (v)

[These ordinates are always so very small, that it is necessary to plot them on a larger scale than that used for abscissæ]

18 **Deflexion** —The maximum ordinate of the Elastic Curve in each Span—commonly called the Deflexion—is the only ordinate of any practical interest Its numerical calculation is always one of considerable labor The process consists of two parts—

i To find the abscissa (x) of the Sections of max Deflexion

ii To calculate the corresponding ordinate (δ), which is the max Deflexion required

STEP i The sections of maximum Deflexion are defined by the condition

$$\frac{dv}{dx} = 0 \tag{43}$$

Expressing which in Eq (42a, b) the abscissæ (x) required are given by

$$\left.\begin{aligned}&\text{In Span } A_1 A_2, \left(\frac{x^2}{2} - \frac{l'^2}{6}\right) M_1 + \left(l'x - \frac{x^2}{2} - \frac{l'^2}{3}\right) M_2 + \frac{l'}{2} K' \\ &\qquad + l' \int_0^x M dx = -\, EI\,(v_1 - v_2)\end{aligned}\right\} \tag{44a}$$

$$\left.\begin{aligned}&\text{In Span } A_2 A_3, \left(\frac{x^2}{2} - \frac{l''^2}{6}\right) M_3 + \left(l''x - \frac{x^2}{2} - \frac{l''^2}{3}\right) M_2 + \frac{l''}{2} K'' \\ &\qquad + l'' \int_0^x M dx = -\, EI\,(v_3 - v_2)\end{aligned}\right\} \tag{44b}$$

The levels (v_1, v_2, v_3) of the Supports are supposed given, (usually assumed zero), the values of the integral $\int_0^x M dx$ are given in Table below, and those of K', K″ in Art 8, for the most useful cases of practice Substituting these values into (44a, b), there result algebraic equations for finding the required abscissa (x) in either Span

On examining the Table of values of $\int_0^x M dx$, it will be seen that, for continuous Loads (the most useful in practice), this equation will usually be a cubic in x, and therefore somewhat troublesome to solve

The best practical way of solving it is usually to reduce all the co efficients to the simplest *numerical* form possible, and then solve it by "trial"

When one of the roots is recognizable *a priori*, the cubic is immediately reducible to a quadratic, and this happens in two cases —

(1), when the Elastic Curve is *horizontal* at any Support, in which case $x = 0$ is one root of the cubics for the two Spans meeting at that Support, and therefore divides out, thus reducing the equations to quadratics

[This Case always occurs in the two middle Spans of a Symmetric symmetrically loaded Beam of an even number of Spans, e g, see Ex 3]

VALUES OF INTEGRALS USEFUL IN CALCULATING DEFLEXION

LOAD [Span AB A outer Support, B middle Support]	Limit of x	Value of $\int_o^x M\,dx$ [Origin at middle Support B]	Value of $\int_o^x x\,M\,dx$ [Origin at middle Support B]	Value of $\int_o^x\int_o^x M\,dx'$ [Origin at middle Support B]
Single Load ($-$ W) at P	$x < x_1$	$\frac{1}{2} W \frac{x_1}{l} x^2$	$\frac{1}{3} W \frac{x_1}{l} x^3$	$\frac{1}{6} W \frac{x_1}{l} x^3$
AP $= x_1$, BP $= x_2$	$x > x_2$	$\frac{1}{2} W x_1 \left(2x - \frac{x^2}{l} - x_1\right)$	$\frac{1}{6} W x_2 \left(3x^2 - \frac{2x^3}{l} - x_2^2\right)$	$\frac{1}{6} W x_1 \left(3x^2 - \frac{x^3}{l} - 3x_2 x + x_2^2\right.$
Single Load ($-$ W) at middle	$x < \frac{1}{2} l$	$\frac{1}{4} W x^2$	$\frac{1}{6} W x^3$	$\frac{1}{12} W x^3$
	$x > \frac{1}{2} l$	$\frac{1}{8} W (4lx - 2x^2 - l^2)$	$\frac{1}{48} W (12lx^2 - 8x^3 - l^3)$	$\frac{1}{48} W (12lx - 4x^3 - 6l^2x +$
Equal Loads ($-$ W) at equal distances x_2 ($< \frac{1}{2}l$) from A, B [$x_1 = l - x_2$]	$x < x_2$	$\frac{1}{2} W x^2$	$\frac{1}{3} W x^3$	$\frac{1}{6} W x^3$
	$x > x_2, < l - x_2$	$W x_2 (x - \frac{1}{2} x_2)$	$\frac{1}{2} W x_2 (x^2 - \frac{1}{3} x_2^2)$	$\frac{1}{2} W x_2 (x^2 - x_2 x + \frac{1}{3} x_2^2)$
	$x < l - x_2$	$\frac{1}{2} W \left\{2x_1x_2 - (l - x)^2\right\}$	$\frac{1}{6} W \left\{3l(x^2 + x_1x_2) - 2x^3 - l^3\right\}$	$\frac{1}{6} W \left\{(l - x)^3 + 3x_1x_2(2x - l)\right\}$
Uniform Load ($-$ w) over whole Span	Anywhere	$\frac{w}{2}\left(\frac{lx^2}{2} - \frac{x^3}{3}\right)$	$\frac{w}{2}\left(\frac{lx^3}{3} - \frac{x^4}{4}\right)$	$\frac{w}{12}\left(l x^3 - \frac{x^4}{2}\right)$
Uniform Load ($-$ w) on AP	$x < x_2$	$\frac{1}{4} w \frac{x_1^2}{l} x^2$	$\frac{1}{6} w \frac{x_1^2}{l} x^3$	$\frac{1}{12} \frac{wx_1^2}{l} x^3$
AP $= x_1$, (BP $= x_2$ unloaded)	$x > x_2$	$\frac{wx_1^2}{12}(3l - 2x_1) + w\frac{(l-x)^2}{12l}(3x_2^2 - 2lx - l^2)$	$\frac{wx_1^2}{24}(2l - x_1)^2 + \frac{w(l-x)^2}{24}\left\{\frac{2l + 4x}{l} x_2^2 - l^2 - 2lx - 3x^2\right\}$	$\frac{wx_1^2}{24}\left\{2x(l + 2x_2) - (l + x_2)\right.$ $+ \frac{w(l - x)^3}{24l}\left(l^2 + lx - 2x_2^2\right.$
Uniform Load ($-$ w) on BP	$x < x_2$	$w\frac{l^2 - x_1^2}{4l} x^2 - \frac{wx^3}{6}$	$w\frac{l^2 - x_1^2}{6l} x^3 - \frac{wx^4}{8}$	$w\frac{l^2 - x_1^2}{12l} x^3 - \frac{wx^4}{24}$
BP $= x_2$, (AP $= x_1$ unloaded)	$x > x_2$	$\frac{wx_2^2}{12l}(6lx - 3x^2 - 2lx_2)$	$\frac{wx_2^2}{24l}\left(6lx^2 - 4x^3 - lx_2^2\right)$	$\frac{wx_2^2}{24l}(6lx^2 - 2x^3 - 4lx_2x + l$

(2), when the Elastic Curve is *horizontal* at middle of any Span, in which case $x = \frac{1}{2}l$ is a root, and is in fact *the abscissa required*

[This case always occurs in the centre Span of a Symmetric, symmetrically loaded Beam of an odd number of spans, *e g*, *see* Exs 4, 8, 10]

It is worthy of remark, that the maximum Deflexion *seldom occurs at the section of positive maximum Bending Moment*

STEP ii *To calculate* δ (the maximum value of v) This is found by substituting the value of the abscissa (x) of the section of maximum deflexion into Eq (42*a*, *b*) The labor of calculation is much reduced by a preliminary reduction of Eq (42*a*, *b*), thus by help of the relation (44*a*, *b*,) the Eq (42*a*, *b*,) may be reduced to

$$\text{Span } A_1 A_2,\ EI(\delta - v_1) = \frac{x^3}{3l}(M_2 - M_1) - \frac{x^2}{2} M_2 - \int_0^x xM\,dx \qquad (45a)$$

$$\text{Span } A_2 A_3,\ EI(\delta - v_2) = \frac{x^3}{3l'}(M_3 - M_2) - \frac{x^2}{2} M - \int_0^x xM\,dx \qquad (45b)$$

The substitution of the values of x found in Step i, into these Results will give the required maximum Deflexion (δ) far more rapidly than the direct substitution into (42*a*, *b*) The depression v is usually assumed zero

N B—The resulting Deflexion (δ) will usually be *negative*, this indicates *downward* Deflexion

[The Table of values of the integrals $\int_0^x M\,dx$, $\int_0^x xM\,dx$, $\int_0^x \int_0^x M\,dx$ given above will enable any one to calculate the Deflexion *without any knowledge of Integral Calculus whatever* for all the most useful cases of practice As already remarked the actual calculation will always be laborious, as the Equation which gives the abscissa (x) of δ is *usually a cubic*

The maximum Deflexion may, however, also be found roughly—(usually with sufficient accuracy)—by plotting a few ordinates of the Elastic Curve (on an exaggerated scale) calculated by Eq (42*a*, *b*) The probable value of the maximum ordinate may then be picked out by inspection of the figure This is also rather laborious]

[CAUTION —From a hasty generalization of the fact, that a Continuous Beam is commonly in condition of a succession of Supported Beams and Cantilevers, Beginners often make the mistake of attempting to calculate the Deflexion in any Span by calculating the partial Deflexions of those portions of each Span which are in condition of Supported Beams and Cantilevers. This is a procedure, however, which requires great caution, and to effect it properly would in fact be *more troublesome than the process developed in the Text*]

Hardly any of the Results (*e g*, values of m'', m''', n'', n'', used in Rankine's Manuals of Applied Mechanics and Civil Engineering), for the ordinary cases of Cantilevers and Supported Beams, are really applicable to the cases of Cantilevers and Supported Beams as occurring in Continuous Beams

Those Results are, in fact, subject to the limitations,

(1) CANTILEVER, The 'Neutral Surface' must be *horizontal* (or $\perp^r$ to the Loads) at the fixed End

(2). SUPPORTED BEAM, The 'Neutral Surface' must be at same level, and of same slope at the two Supports

Now these two Conditions obtain only in particular cases in certain Spans of Continuous Beams, so that these simpler Results are seldom applicable to the latter

The error that may be made by an incautious use of Results proper only to Supported Beams and Cantilevers, is often considerable, as may be seen below —

Continuous Uniform Beams Equal Spans, Uniform Load			
	Reference	Distance of max Deflexion from End Support	
		True distance	Supposed approximate distance
Beam of two Spans,	Ex 7	42153 l	375 l
Beam of three Spans, (Side Spans),	Ex 8	446 l	4 l

It is obvious that these discrepancies would *amount to many feet* in large Spans

17. Symmetric Beam, under Symmetric Load —The solution in this Case, which is a common one in practice, is much facilitated by observing that in consequence of the complete symmetry both of the Spans and Load *about the middle point* (O), all quantities such as R, F, M, v, δ are equal (in magnitude) by pairs at equal distances from the middle

This consideration reduces the number of independent quantities to be found by one-half Thus—

$$R_1 = R_{n+1}\ R_2 = R_n,\ R_3 = R_{n-1}, \&c, \tag{46}$$

$$M_1 = M_{n+1}\ M_2 = M_n,\ M_3 = M_{n-1},\ \&c, \tag{47}$$

$$F_{+\xi} = -F_{-\xi},\ M_{+\xi} = M_{-\xi} \tag{48}$$

Case of middle Span —In a Symmetric Beam under Symmetric Load with an odd number of Spans, let m be the number of the middle Span (counting from either end), W_m the Total Load on it, then by the condition of symmetry which gives $M_{m+1} = M_m$, and Eq 28a, b,

$$R'_m = R'_m = \tfrac{1}{2} W_m = R''_m = R''_m, \tag{49}$$

Thus the Shear-Re-actions of this Span are *the same as if this Span were discontinuous* at its ends, hence—

"The Shearing Force throughout centre Span of a Symmetric, symmetrically loaded Continuous Beam is precisely the same in all respects as if this Span were discontinuous", (49)

18 Transverse Strength —The expressions for the Longitudinal Stresses (C, T), Moment of Resistance ($\mathfrak{M}$), and Shearing Resistance ($\mathfrak{F}$), which are investigated in ordinary Treatises on Applied Mechanics for the case of "Supported Beams" are usually established in a perfectly general manner, and are therefore applicable to case of Continuous Beams

It must be remembered that the *character* of longitudinal Stress depends on the sign of the Bending Moment (M), and that there are therefore

(1) CONTRACTION, and COMPRESSIVE STRESS along all parts on the concave side of the neutral Surface,

(2) EXTENSION, and TENSILE STRESS along all parts on the convex side of the neutral Surface

The expressions for C, T, 𝕸, 𝕱, with the values of M, F of this Paper, enable all questions on TRANSVERSE STRENGTH of Continuous Uniform Beams to be solved

[The Results of this Paper are, however, in strictness limited to Uniform Beams, see Art. 10, so that the sections of (absolute) maximum Bending Moment, and of (absolute) maximum Shear must be held in strictness to *fix the scantling of the whole Beam*]

Examples of Continuous Uniform Beams under Uniform Steady Load

19 Here follow the reduced Results for the simple Cases of Two Spans, Three Spans, &c, under UNIFORM STEADY LOAD—the only case usually worked out

The notation is the same as explained in Arts 2, 11, in addition to which

O is the middle point of any Span, and origin of the abscissa (ξ),

w_1, w_2, w_3, &c, the uniform load-intensities per length unit,	in the spans l_1, l_2, l_3, &c
I_1, I_2, I_3 &c, the points of inflexion of the 'neutral surface',	
m_1, m_2, m_3, &c, the points of (positive) max Bending Moment,	
E_1, E_2, E_3, &c, the points of max deflexion,	
$M_{0,1}$ $M_{0,2}$ $M_{0,3}$ &c, the (positive) maximum Bending Moments,	

x', x'' the abscissæ of any section P in any span, x', x'' being measured from the right and left Supports respectively *of that Span*

Ex 1 *Two spans each uniformly loaded*

w_1, w_2, the uniform load-intensities per length unit of Spans l_1, l_2

R_1, R_2, R_3 the Total Re actions at A_1, A_2, A_3

R'_1, R''_1, R'_2, R''_2 the Shear-Re-actions of l_1, l_2, respectively

R'_1, R''_1; R'_2, R''_2, the Re actions of spans l_1, l_2, if *discontinuous*

M_2 the Moment of Re action-Couple at A_2

$M_{0,1}$ $M_{0,2}$ the (positive) max Bending Moments in span l_1, l_2

Observing that since the Beam is simply supported at A_1, A_3, the Re action-Couples at A_1, A_3 both vanish (Art 13), the value of M_2 is given at once by Clapeyron's Theorem, (Art 9),

$$2\,M_2\,(l_1 + l_2) = -\tfrac{1}{4}\,(w_1\,l_1^3 + w_2\,l_2^3)\ldots \tag{50}$$

Observing also that—

$$R_1 = \tfrac{1}{2}\,w_1\,l_1 = R''_1, \text{ and } R'_2 = \tfrac{1}{2}\,w_2\,l_2 = R''_2,$$

The values of the Shear-Re actions are given at once by Eq (30, 31)

$$\left.\begin{aligned} R'_1 &= \tfrac{1}{2}\,w_1\,l_1 + \frac{M_2}{l_1}, \quad R''_1 = \tfrac{1}{2}\,w_1\,l_1 - \frac{M_2}{l_1}, \\ R'_2 &= \tfrac{1}{2}\,w_2\,l_2 - \frac{M_2}{l_2}, \quad R''_2 = \tfrac{1}{2}\,w_2\,l_2 + \frac{M_2}{l_2}, \end{aligned}\right\} \tag{51}$$

The values of the Total Re actions are given at once by Eq (36, 37)

$$R_1 = R'_1,\ R_2 = w_1\,l_1 + w_2\,l_2 - (R_1 + R_3),\ R_3 = R''_2 \tag{52}$$

The Shearing Force at any point P,

$$\left.\begin{aligned} &\text{SPAN } l_1,\ F = R'_1 - w x = -(R''_1 - w_1 x'') \\ &\text{SPAN } l_2,\ F = R'_2 - w x' = -(R'' - w_2 x'') \end{aligned}\right\} \qquad (53)$$

Also at A_1, $F'_1 = R_1$, at A_2, $F''_1 = -R''_1$, $F'_2 = R'_2$, at A_3, $F''_2 = -R''_2$. (54)

The Bending Moment at any point P,

$$\left.\begin{aligned} &\text{SPAN } l_1,\ M = R'_1 x - \frac{w_1 x'^2}{2} = R''_1 x'' - \frac{w_1 x''^2}{2} \\ &\text{SPAN } l_2,\ M = R'_2 x' - \frac{w_2 x'^2}{2} = R''_2 x'' - \frac{w_2 x''^2}{2} \end{aligned}\right\} \qquad (55)$$

There are usually two inflexions, one in each span, whose abscissæ are,

$$\left.\begin{aligned} &\text{SPAN } l_1,\ x' = \frac{2R'_1}{w_1} = l_1 + \frac{2M_2}{w_1 l_1} \\ &\text{SPAN } l_2,\ x'' = \frac{2R''_2}{w_2} = l_2 + \frac{2M_2}{w_2 l_2} \end{aligned}\right\} \qquad (56)$$

The Bending moment has usually three maxima, viz., two positive maxima—one in each span,—and one negative maximum,

$$\left.\begin{aligned} &\text{SPAN } l_1,\ M_{0,1} = \tfrac12 \frac{R'^2_1}{w_1},\ \text{where } x' = \frac{R'_1}{w_1}, \text{and } F = 0 \\ &\text{At } A_2,\ M = M_2 \text{ a negative maximum} \\ &\text{SPAN } l_2,\ M_{0,2} = \tfrac12 \frac{R''^2_2}{w_2},\ \text{where } x'' = \frac{R''_2}{w_2}, \text{and } F = 0 \end{aligned}\right\} \qquad (57)$$

Thus the sections of no Shear and of positive maximum Bending Moment, bisect the segments $A_1 I_1$, $A_3 I_3$ between the End Supports and Inflexions.

Ex 2. *Two equal spans each uniformly loaded.*—This is only a special case of preceding, but sufficiently important to be worth recording. The Results which are easily derived from the last (by writing $l_1 = l_2 = l = 2c$ in the last), are

Moment of Re action-Couple, $M_2 = -\frac{1}{16}(w_1 + w_2) l^2 = -\frac14 (w_1 + w_2) c^2$. (58)

$$\left.\begin{aligned} &\textit{Shear Re actions},\ R'_1 = \frac{7w_1 - w_2}{16} l,\ R''_1 = \frac{9w_1 + w_2}{16} l \\ &R'_2 = \frac{w_1 + 9w_2}{16} l,\ R''_2 = \frac{7w_2 - w_1}{16} l \end{aligned}\right\} \qquad (59)$$

Total Re actions $R_1 = \frac{7w_1 - w_2}{16} l$, $R_2 = \frac58 (w_1 + w_2) l$, $R_3 = \frac{7w_2 - w_1}{16} l$, (60)

The general values of F, M, and of the maximum Bending Moments cannot be more simply expressed than in last Example, *q v*.

There are *usually* two inflexions I_1, I_2, one in each span, given by

$$A_2 I_1 = \left(1 + \frac{w_2}{w_1}\right)\frac{l}{8},\quad A_2 I_2 = \left(1 + \frac{w_1}{w_2}\right)\frac{l}{8} \qquad (61)$$

It is worthy of note that if w_2 diminishes whilst w_1 remains constant, I_1 approaches A_2, I_2 recedes from A_2 and R''_2 decreases, until

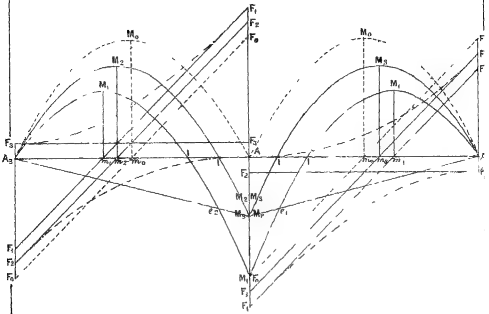
when $w_2 = \frac17 w_1$, $R''_2 = 0$, $A_2 I_1 = \frac17 l$, $A_2 I_2 = l$,

so that the left span $A_2 I_2$ ceases to press on the Support A_3, and is everywhere convex upward.

If w_2 continue to decrease $< \frac17 w_1$, R''_2 becomes negative showing that Tension is required at A_3, until finally

CONTINUOUS UNIFORM BEAM OF TWO EQUAL SPANS

DIAGRAMS OF SHEARING FORCE AND BENDING MOMENT FOR VARYING UNIFORM LOAD



EXPLANATION

	Load	Shearing Force F: Span A_1A_2	Shearing Force F: Span A_2A_3	Bending Moment M: Span A_1A_2	Bending Moment M: Span A_2A_3	Reference
	Spans discontinnous, uniformly loaded,	$F_0 m_0 F_0$	$F_0 m_0 F_0$	$A_1 M_0 A_2$	$A_2 M_0 A_3$	
Continuous Beam.	A_1A_2 unloaded A_2A_3 uniformly loaded, ..	$F_2 F_2$	$F_2 m_2 F_2$	$A_1 M_2$	$M_2 IM_2 A_3$	Ex 2
	A_1A_2, A_2A_3 both uniformly loaded, .	$F_1 m_1 F_1$	$F_1 m_1 F_1$	$A_1 M_1\ IM_1$	$M_1 IM_1 A_3$	Ex 3
	A_1A_2 uniformly loaded, A_2A_3 unloaded, .	$F_3 m_3 F_3$	$F_3 F_3$	$A_1 M_3\ IM_3$	$M_3 A_3$	Ex 2
		Greatest Values F		Greatest Values M		
	Moving uniform load, . positive,	$F_1 A$	$F_1 F_3$	$A_1 M_3\ I$	$IM_2 A_3$	Ex 19
	Moving uniform load, . negative	[illegible] F_1	$A_2 F_2$	$A_1 e_1 M_1$	$M_1 e_2 A_3$	[illegible]

The ordinates show the Greatest Values F M at each section

$$\text{when } w_2 = 0,\ A_2 I_1 = \tfrac{1}{8}l,\ A_2 I_2 = \infty,\ R''_2 = -\frac{1}{16} w_1 l$$

[*Plate* XIX shows the Diagrams of Shearing Force and Bending Moment for this Beam for the particular Cases, 1°, $w_1 = 0$, w_2 finite, 2°, $w_1 = w_2$, 3° w_1 finite, $w_2 = 0$ as well as the corresponding Curves (dotted lines) for *discontinuous* Spans for sake of comparison for references, *see Plate* XIX]

To find the abscissæ of the sections of maximum Deflexion, substitute $M_1 = 0$, $M_2 = -\frac{1}{16}(w_1 + w_2) l^2$, $M_3 = 0$, and the values of K', K'', $\int_0^x M dx$ from the Tables of Arts 8 and 16 into Eq (44*a*, *b*) It will be found on reducing that the abscissa (x) is given by solution of the cubics,

$$\text{SPAN } l_1,\ \frac{x^3}{l^3} - \tfrac{3}{16}\left(9 + \frac{w_2}{w_1}\right)\frac{x^2}{l^2} + \tfrac{3}{8}\left(1 + \frac{w_2}{w_1}\right)\frac{x}{l} + \tfrac{1}{8}\left(1 - \frac{w_2}{w_1}\right) = 0, \quad (62a)$$

$$\text{SPAN } l_2,\ \frac{x^3}{l^3} - \tfrac{3}{16}\left(9 + \frac{w_1}{w_2}\right)\frac{x^2}{l^2} + \tfrac{3}{8}\left(1 + \frac{w_1}{w_2}\right)\frac{x}{l} + \tfrac{1}{8}\left(1 - \frac{w_1}{w_2}\right) = 0, \quad (62b)$$

The solution cannot be conveniently expressed unless the ratio $w_1 : w_2$ is given in a *numerical* form, (*see* next example) [Observe that only the positive value of x which is $< l$ will suit this Problem]

To find the maximum Deflexion (δ), Results (45*a*, *b*) give, on substituting for M_1, M_2, M_3, $\int_0^x xMdx$ (the last from the Table), after reduction

$$\text{SPAN } l_1,\ \delta_1 = \frac{w_1 c^4}{6EI}\left\{12\frac{x^4}{l^4} - 2\left(9 + \frac{w_2}{w_1}\right)\frac{x^3}{l^3} + 3\left(1 + \frac{w_2}{w_1}\right)\frac{x^2}{l^2}\right\} \quad \ldots \quad (63a),$$

$$\text{SPAN } l_2,\ \delta_2 = \frac{w_2 c^4}{6EI}\left\{12\frac{x^4}{l^4} - 2\left(9 + \frac{w_1}{w_2}\right)\frac{x^3}{l^3} + 3\left(1 + \frac{w_1}{w_2}\right)\frac{x^2}{l^2}\right\} \quad (63b),$$

in which the values of $x \div l$ derived from Eq (62*a*, *b*) are to be substituted

These will generally be *negative* quantities, indicating downward Deflexion

Ex 8 *Uniformly loaded, Uniform Beam of two equal spans* This case is more common in practice than the last, of which it is a special case The Results (easily derivable from the last Example) are—

Moment of Re-action-Couple $M_2 = -\frac{1}{8} wl^2 = -\frac{1}{8} wc^2$ (64)

Shear Re actions $R'_1 = \frac{3}{8} wc = R''_3$, $R''_1 = \frac{5}{8} wc = R'_3$ (65)

Total Re-actions $R_1 = \frac{3}{8} wc = R_3$, $R_2 = \frac{5}{4} wc$ (66)

Shearing Force $F'_1 = \frac{3}{8} wc = -F''_3$, $-F''_1 = \frac{5}{8} wc = F'_2$ (67)

$$\left.\begin{array}{l}\text{SPAN } l_1,\ (A_1 P = x'),\ F = \tfrac{3}{8} wc - wx' \\ \text{SPAN } l_2,\ (A_3 P = x''),\ F = \tfrac{3}{8} wc - wx''\end{array}\right\} \quad (68)$$

Bending Moment —

$$\left.\begin{array}{l}\text{SPAN } l_1,\ (A_1 P = x'),\ M = \tfrac{3}{8} wcx' - \dfrac{wx'^2}{2} \\ \text{SPAN } l_2,\ (A_3 P = x''),\ M = \tfrac{3}{8} wcx'' - \dfrac{wx''^2}{2}\end{array}\right\} \quad (69)$$

There are two inflexions, (I_1, I_2), $A_2 I_1 = \frac{1}{4} c = A_2 I_2$ (70)

$$\left.\begin{array}{l}\text{The Bending Moment is a negative maximum, } M_2 = -\tfrac{1}{8} wc^2 \text{ at } A_2, \\ \quad\text{and a positive maximum, } M_0 = \tfrac{9}{128} wc^2 \text{ at middles of } A_1 I_1,\ A_3 I_2\end{array}\right\} \quad (71).$$

[*Plate* XIX shows the Diagrams of Shearing Force ($F_1 m_1 F_1$, $F_1 m_1 F_1$) and Bending Moment ($A_1 M_1 I e_1 M_1$, $M_1 e_2 I M_1 A_3$) for this case]

To find abscissæ of sections of maximum Deflexion, writing $w_1 = w_2$ in (62*a*, *b*), both Results become after reduction

$$\frac{x^2}{l^2} - \frac{15}{8}\frac{x}{l} + \frac{3}{4} = 0, \text{ whence } \frac{x}{l} = \frac{15 \pm \sqrt{33}}{16} = 57847 \qquad (72)$$

Both Results (63*a*, *b*) reduce to

$$\delta_1 = \frac{w c^4}{6\,\mathrm{EI}}\left\{12\frac{x^4}{l^4} - 20\frac{x^3}{l^3} + 6\frac{x^2}{l^2}\right\} = -\ 0867\,\frac{wc^4}{\mathrm{EI}}, \text{ nearly} \qquad (73)$$

[The negative sign indicates *downward* Deflexion]

Ex 4 *Three uniformly loaded Symmetric Spans, Symmetric Load*

l_1, l_2, l_3, the Spans, $l_1 = l_3$

w_1, w_2, w_3, the load intensities per length unit, $w_1 = w_3$

Hence since for simply Supported Ends, $\mathrm{M}_1 = \mathrm{M}_4 = 0$, Clapeyron's Theorem gives, (Art 9),

$$2\,\mathrm{M}_2\,(l_1 + l_2) + \mathrm{M}_3\,l_2 = -\tfrac{1}{4}\,(w_1 l_1^3 + w_2 l_2^3) \qquad (74),$$

and by the symmetry $\mathrm{M}_2 = \mathrm{M}_3$

$$\therefore \mathrm{M}_2 = -\tfrac{1}{4}\,\frac{w_1 l_1^3 + w_2 l_2^3}{2\,l_1 + 3\,l_2} = \mathrm{M}_3 \qquad (75)$$

$$\left.\begin{array}{l} \text{By (30, 31), } \mathrm{R}'_1 = \tfrac{1}{2} w_1 l_1 + \dfrac{\mathrm{M}_2}{l_1} = \mathrm{R}''_3,\ \mathrm{R}''_1 = \tfrac{1}{2} w_1 l_1 - \dfrac{\mathrm{M}_2}{l_1} = \mathrm{R}'_3 \\ \text{By (48), } \mathrm{R}'_2 = \tfrac{1}{2} w_2 l_2 = \mathrm{R}''_2 \end{array}\right\} \qquad (76)$$

$$\text{By (36, 37), } \mathrm{R}_1 = \mathrm{R}'_1,\ \mathrm{R}_2 = \tfrac{1}{2} w_1 l_1 + \tfrac{1}{2} w_2 l_2 - \frac{\mathrm{M}_2}{l_1} = \mathrm{R}_3,\ \mathrm{R}_4 = \mathrm{R}''_3 \qquad (77)$$

$$\left.\begin{array}{lll} \textit{Side Spans}, & x = \mathrm{A}_1\mathrm{P} \text{ or } \mathrm{A}_4\mathrm{P}, & \pm\mathrm{F} = \mathrm{R}_1 - w_1 x \\ \textit{Centre Span}, & \pm\xi = \mathrm{OP}, & \pm\mathrm{F} = w_2\,\xi \end{array}\right\} \qquad (78)$$

$$\left.\begin{array}{lll} \textit{Side Spans}, & x = \mathrm{A}_1\mathrm{P} \text{ or } \mathrm{A}_4\mathrm{P}, & \mathrm{M} = \mathrm{R}_1 x - \tfrac{1}{2} w_1 x^2 \\ \textit{Centre Span}, & \pm\xi = \mathrm{OP}, & \mathrm{M} = \mathrm{M}_2 + \tfrac{1}{2} w_2\,(c_2^2 - \xi^2) \end{array}\right\} \qquad (79).$$

$$\left.\begin{array}{lll} \textit{Side Spans}, & \text{Inflexion at I}, & \mathrm{A}_1\mathrm{I} = \dfrac{2}{w_1}\mathrm{R}'_1 = \mathrm{A}_4\mathrm{I} \\ \textit{Centre Span}, & \text{Inflexions at I, I}, & \mathrm{OI} = \pm\sqrt{c^2 + \dfrac{2}{w_2}\mathrm{M}_2} \end{array}\right\} \qquad (80)$$

$$\left.\begin{array}{ll} \textit{Side Spans}, & \text{Positive Maximum of M is } \mathrm{M}_0 = \dfrac{1}{2w_1}\mathrm{R}_1^2 \\ & \text{at middles of segments } \mathrm{A}_1\mathrm{I}, \mathrm{A}_4\mathrm{I} \\ \textit{Centre Span}, & \text{Negative maxima of M, viz, } \mathrm{M}_2 \text{ or } \mathrm{M}_3 \text{ at } \mathrm{A}_2, \mathrm{A}_3, \\ & \text{also at O, } \mathrm{M}_0 = \mathrm{M}_2 + \tfrac{1}{2} w c_2^2 \\ & [\mathrm{M}_0 \text{ is a max if positive, minimum if negative}] \end{array}\right\} \qquad (81)$$

Ex 5 *Three uniformly loaded Symmetric Spans* ($l_1 = l_3$)

By Clapeyron's Theorem, observing that $\mathrm{M}_1 = 0 = \mathrm{M}_4$

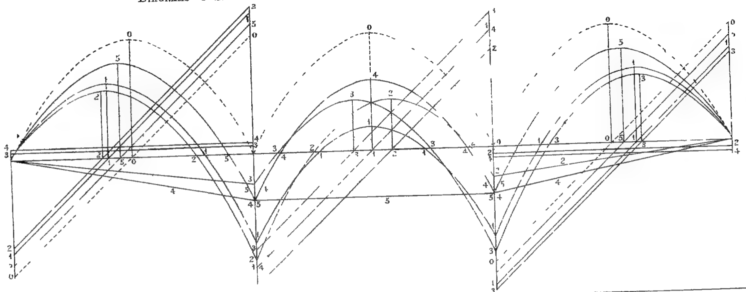
$$\left.\begin{array}{l} 2\,\mathrm{M}_2\,(l_1 + l_2) + \mathrm{M}_3\,l_2 = -\tfrac{1}{4}\,(w_1 l_1^3 + w_2 l_2^3) \\ 2\,\mathrm{M}_3\,(l_2 + l_1) + \mathrm{M}_2\,l_2 = -\tfrac{1}{4}\,(w_3 l_1^3 + w_2 l_2^3) \end{array}\right\} \qquad (82)$$

$$\left.\begin{array}{l} \text{whence } \mathrm{M}_2 = -\dfrac{2\,w_1(l_1 + l_2)\,l_1^3 + w_2\,(2\,l_1 + l_2)\,l_2^3 - w_3\,l_1^3\,l_2}{4\,(2\,l_1 + 3\,l_2)\,(2\,l_1 + l_2)} \\ \mathrm{M}_3 = -\dfrac{2\,w_3(l_1 + l_2)\,l_1^3 + w_2\,(2\,l_1 + l_2)\,l_2^3 - w_1\,l_1^3\,l_2}{4\,(2\,l_1 + 3\,l_2)\,(2l_1 + l_2)} \end{array}\right\} \qquad (83)$$

[It is not worth while developing the other Results of this Case, as the formulæ become complex The Results (83), however, are required for investigation of effect of Moving Load on a Three Span Beam]

CONTINUOUS UNIFORM BEAM OF THREE EQUAL SPANS

Diagrams of Shearing Force and Bending Moment for varying Uniform Load



Beam	Load			Shearing Force Diagrams			Bending Moment Diagrams		
	Left Span	Centre Span	Right Span	Left Span	Centre Span	Right Span	Left Span	Centre Span	Right Span
Continuous Beam, Ex. 4 5 Art. 346	Loaded Loaded Empty Empty Loaded	Loaded Loaded Loaded Loaded Empty	Loaded Empty Loaded Empty Loaded	Oblique Line, 1 Oblique Line, 2 Horizontal Line, 3 Horizontal Line, 4 Oblique Line, 5	Oblique Line, 1 Oblique Line, 2 Oblique Line, 3 Oblique Line, 4 Nil	Oblique Line, 1 Horizontal Line, 2 Oblique Line, 3 Horizontal Line, 4 Oblique Line, 5	Parabola, 1 Parabola, 2 Oblique Line, 3 Oblique Line, 4 Parabola, 5	Parabola 1 Parabola, 2 Parabola 3 Parabola, 4 Horizontal Line, 5	Parabola, 1 Oblique Line, 2 Parabola 3 Oblique Line, 4 Parabola, 5
Discontinuous Spans,	Loaded	Loaded	Loaded	Oblique Line, 0	Oblique Line, 1	Oblique Line, 0	Parabola, 0	Parabola, 0	Parabola 0

[*Plate* XX exhibits the Shearing Force and Bending Moment Diagrams for a Continuous Beam of Three Equal Spans, each *under uniform Load*, for the most important values of the ratios of $w_1 : w_2 : w_3$, viz,

(1), $w_1 = w_2 = w_3$, (4), $w_1 = 0 = w_3$,
(2), $w_1 = 0$, $w_2 = w_3$, (5), $w_1 = w_3$, $w_2 = 0$,
(3), $w_1 = w_2$, $w_3 = 0$,

as well as the corresponding Diagrams for *discontinuous* Spans for comparison with the rest]

Ex 6 *Uniformly loaded Beam of* n *Equal Spans*—This case is approximated to in the Rafters of some Roof Trusses, which are often of uniform section throughout, and supported on several equidistant Supports (Ridge, Strut heads, and Wall-plate), and also tolerably uniformly loaded

The Total Re actions (R_1, R_2, &c) are equal and opposite to the Pressures of the Rafter on its Supports, and, are therefore, the "Equivalent Loads at the Joints" required as the "first Step"* in finding the DIRECT STRESSES in the Bars of the Truss

The greatest of the Moments of Re action-Couples (M_1, M_2, &c) is the maximum Bending Moment (M_m) required in calculating the stress due to flexure,† in the Rafter

[In the investigation of DIRECT STRESSES in Roof-Trusses‡ and again in the special investigation of the additional (longitudinal) Stresses due to Transverse Strain in RAFTERS † it is often preferred to use the Hypothesis of Free Joints ‡ in finding the "Equivalent Loads at the Joints", and "Maximum Bending Moment", as the values so found are at once obtained in an elementary manner, and it is *doubtful whether the new values* obtained by the present method *are really better approximations*

It must be remembered that the numerical values here given *depend essentially on the rigidity of the Supports* (Art 7) Now in a Framed Truss, this rigidity cannot exist The Truss will deflect *as a whole*, and along with it the Rafter, so that the Rafter Joints will certainly settle, and by amounts which are small, but probably of same order as the Deflexions of the Rafter segments, and therefore not negligible from the Equation of the Elastic Curve The proper course would undoubtedly be, to make some allowance for these settlements (the v_1, v_2, v_3, &c , of Eq 21), but it would greatly complicate the investigation

Meanwhile it is a matter of opinion which set of values are the more approximate]

Let w = load-intensity per length-unit of each span (l),

$8K' = 8K'' = -\frac{1}{4} wl^3 = -2wc^3$ for every span (Table, Art 8)

Observing that for a Beam simply supported at the ends $M_1 = M_{n+1} = 0$, Clapeyron's Theorem gives a series of $(n-1)$ equations of the form, (after dividing by $l = 2c$)

$$\left.\begin{array}{rl} 4\,M_2 + M_3 = -2wc^2 = & M_{n-1} + 4\,M_n \\ M_2 + 4\,M_3 + M_4 = -2wc^2 = & M_{n-2} + 4\,M_{n-1} + M_n \\ M_3 + 4\,M_4 + M_5 = -2wc^2 = & M_{n-3} + 4\,M_{n-2} + M_{n-1} \\ +\quad\;\; + \quad = -2wc^2 = & \quad + \qquad\quad + \end{array}\right\} \quad .. \qquad (84)$$

Between which $(n-1)$ equations, the $\overline{n-1}$ quantities (M) are easily found when

* *See* the Author's "Manual of Applied Mechanics", Art 116

† *See* the Author's Paper "On Rafters and Purlins", No CXXI of Professional Papers on Indian Engineering, [Second Series]

‡ *See* "Manual of Applied Mechanics", Art 113, *et seq*

not very numerous The Load and Beam being symmetric about the middle, (Art 17)

$$M_2 = M_n, \quad M_3 = M_{n+1}, \quad M_4 = M_{n-2}, \text{ \&c , \&c ,} \tag{85}$$

so that only half of them require independent calculation

The Shear-Re actions, and Total Re-actions are now easily calculable by Results (30, 31) and (36, 37)

The Shearing Force in p^{th} Span is

$$F = R_p - wx' = -(R''_p - wx''), \tag{86}$$

The Bending Moment in p^{th} Span is

$$M = M_p + R'_p x' - \tfrac{1}{2} wx'^2 = M_{p+1} + R''_p x' - \tfrac{1}{2} wx''^2, \tag{87}$$

In the End Spans this reduces to

$$M = R'_1 x' - \tfrac{1}{2} wx'^2, \; M = R''_{n+1} x'' - \tfrac{1}{2} wx''^2, \tag{88}$$

The inflexions (given by $M = 0$) are generally two in p^{th} span at the sections,

$$x' = \frac{1}{w}\left(R'_p \pm \sqrt{R'^2_p + 2w\,M_p}\right), \; x'' = \frac{1}{w}\left(R''_p \pm \sqrt{R''^2_p + 2w\,M_{p+1}}\right) \tag{89}$$

For the End Spans these reduce to a single point at

$$\text{First Span, } A_1 I_1 = \frac{2}{w} R'_1, \text{ Last Span, } A_{n+1} I_n = \frac{2}{w} R''_{n+1}, \tag{90}$$

The positive maximum Bending Moment occurs at section (given by $F = 0$) where

$$x' = \frac{1}{w} R'_p \text{ or } x'' = \frac{1}{w} R''_p, \tag{91}$$

$$\text{and is } M_{o,p} = M_p + \frac{1}{2w} R'^2_p = M_{p+1} + \frac{1}{2w} R''^2_p, \tag{92}$$

The negative maximum Bending Moments are (M_2, M_3, M_n) over each Support except the End Supports

The Results reduced from the above for the particular cases $n = 2, 3, 4, 5, 6$ are shown below—(for notation, *see* beginning of Art 19)—

Ex 7 *Two equal Spans* $M_2 = -\frac{1}{8} wc^2$

$R'_1 = \frac{3}{8} wc = R''_2, \quad R''_1 = \frac{5}{8} wc = R'_2$

$R_1 = \frac{3}{8} wc = R_3, \quad R_2 = \frac{5}{4} wc$

$A_2 I_1 = \frac{1}{4} c = A_2 I_2$

$M_0 = \frac{9}{128} wc^2, \quad A_1 m_1 = \frac{3}{8} c = A_3 m_2$

$\delta_1 = -\cdot 0867 \dfrac{wc^4}{EI} = \delta_2, \quad A_2 E_1 = \cdot 57847\, l = A_3 E_2$

Ex 8 *Three equal Spans* $M_2 = -\frac{1}{10} wc^2 = M_3$

$R'_1 = \frac{4}{10} wc = R''_3, \quad R''_1 = \frac{6}{10} wc = R'_3, \quad R'_2 = wc = R''_2$

$R_1 = \frac{4}{10} wc = R_4, \quad R_2 = \frac{11}{10} wc = R_3$

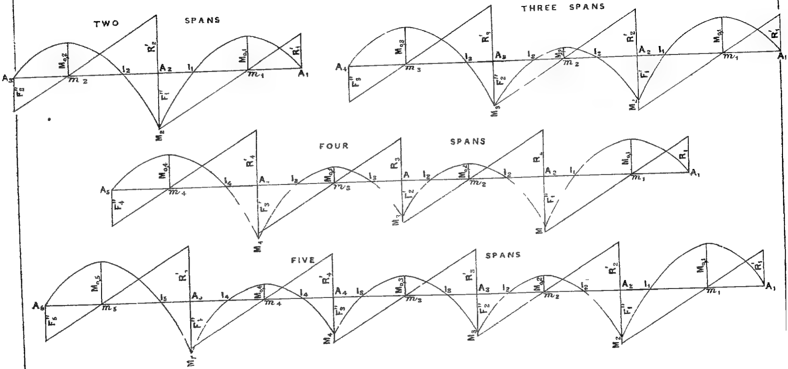
$A_2 I_1 = \frac{2}{10} c = A_4 I_3, \quad O I_2 = \pm \dfrac{c}{\sqrt{5}}$

$M_{o,1} = \frac{8}{100} wc^2 = M_{o,3}, \quad M_{o,2} = \frac{1}{40} wc^2 \text{ (at O)}$

$A_1 m_1 = \frac{4}{10} c = A_4 m_3,$

$\delta_1 = -\cdot 1102 \dfrac{wc^4}{EI} = \delta_3, \quad A_2 E_1 = \cdot 554\, l = A_4 E_3.$

CONTINUOUS UNIFORM BEAMS—EQUAL SPANS—UNIFORM LOAD



Ex 9 *Four equal Spans* $M_2 = -\frac{3}{7} wc^2 = M_4$, $M_3 = -\frac{2}{7} wc^2$

$R'_1 = \frac{11}{14} wc = R''_4$, $R''_1 = \frac{17}{14} wc = R'_4$, $R'_2 = \frac{15}{14} wc = R''_3$, $R''_2 = \frac{13}{14} wc = R'_3$

$R_1 = \frac{11}{14} wc = R_5$, $R_2 = \frac{16}{7} wc = R_4$, $R_3 = \frac{13}{7} wc$

$A_2 I_1 = \frac{3}{7} c = A_5 I_4$, $A_3 I_2 = \frac{18 \pm \sqrt{57}}{14} c = A_3 I_3$

$M_{0,1} = \frac{121}{392} wc^2 = M_{0,4}$, $M_{0,2} = \frac{57}{392} wc^2 = M_{0,3}$

$A_1 m_1 = \frac{11}{14} c = A_5 m_4$, $A_2 m_2 = \frac{13}{11} c = A_3 m_3$

Ex 10 *Five equal Spans* $M_2 = -\frac{8}{19} wc^2 = M_5$, $M_3 = -\frac{6}{19} wc^2 = M_4$

$R'_1 = \frac{15}{19} wc = R''_5$, $R''_1 = \frac{23}{19} wc = R'_5$, $R'_2 = \frac{20}{19} wc = R''_4$, $R''_2 = \frac{18}{19} wc = R'_4$, $R'_3 = wc = R''_3$

$R_1 = \frac{15}{19} wc = R_6$, $R_2 = \frac{43}{19} wc = R_5$, $R_3 = \frac{37}{19} wc = R_4$

$A_2 I_1 = \frac{8}{19} c = A_5 I_5$, $A_3 I_2 = \frac{18 \pm 4\sqrt{6}}{19} c = A_4 I_4$, $OI_3 = \pm\sqrt{\frac{7}{19}}\, c$

$M_{0,1} = \frac{225}{722} wc^2 = M_{0,5}$, $M_{0,2} = \frac{18}{361} wc^2 = M_{0,4}$, $M_{0,3} = \frac{7}{38} wc^2$ at O

$A_1 m_1 = \frac{15}{19} c = A_6 m_5$, $A_3 m_2 = \frac{18}{19} c = A_4 m_4$

Ex 11 *Six equal Spans* $M_2 = -\frac{11}{26} wc^2 = M_6$, $M_3 = -\frac{4}{13} wc^2 = M_5$, $M_4 = -\frac{9}{26} wc^2$

$R'_1 = \frac{41}{52} wc = R''_6$, $R''_1 = \frac{63}{52} wc = R'_6$, $R'_2 = \frac{55}{52} wc = R''_5$

$R''_2 = \frac{49}{52} wc = R'_5$, $R'_3 = \frac{51}{52} wc = R''_4$, $R''_3 = \frac{53}{52} wc = R'_4$

$R_1 = \frac{41}{52} wc = R_7$, $R_2 = \frac{59}{26} wc = R_6$, $R_3 = \frac{25}{13} wc = R_5$, $R_4 = \frac{53}{26} wc$

$A_2 I_1 = \frac{11}{26} c = A_6 I_6$, &c , &c

$M_{0,1} = \frac{1681}{5408} wc^2 = M_{0,6}$, &c , &c

$A_1 m_1 = \frac{41}{52} c = A_7 m_6$, &c , &c

[*Plate* XXI shows the Diagrams of Shearing Force and Bending Moment for the above Beams, of from two to five spans The Figures are all drawn on same scales, with same Spans and same load intensity for purposes of comparison]

20 Effect of Moving Load —Under a Moving Load it is obvious that both Shearing Force and Bending Moment change continuously *at every section* during the passage of the Load passing through certain Greatest Values at each section usually at different stages of the passage of the Load these will be styled* the GREATEST SHEARING FORCE and GREATEST BENDING MOMENT, and denoted by **F**, **M** respectively

Their *complete* investigation in a Continuous Beam is always tedious, (and is usually omitted in English works) One or two simple useful Cases only will be briefly investigated here

* In contradistinction to the terms "Maximum Shearing Force", "Maximum Bending Moment", which will be used to denote the Maximum values of the Shearing Force and Bending Moment of the whole Beam

There are usually two inflexions in the Elastic Curve *in each Span* of a Continuous Beam which define the regions of $\pm$ Curvature and of $\pm$ Bending Moment. Under Steady Load these occupy a definite position, but under Moving Load these points shift continuously; throughout the region of displacement of a particular inflexion, the Bending Moment is liable to change of sign, and is therefore susceptible of two Greatest Values (one +, one −) at each section in that region.

[The Investigations following apply *solely to the Moving Load*. In applying the Results to real Girders the portions of F, M due to the Permanent Load must of course be combined with these to give the Resultant Shearing Force and Bending Moment.

It follows of course that any small values of F, M due to Moving Load which are of opposite sign to those due to the Permanent Load are of no importance.]

Ex 12. *Two Span Beam under uniform moving Load*. The process of finding **F**, **M** may be divided into five Steps:

STEP I	To trace the variation of K′, K″	*N.B.*—For case of equal Spans, make $l_1 = l$ throughout
STEP II	To trace the variation of M_2	
STEP III	To trace the variation of R'_1, R''_1, R'_2, R''_2	
STEP IV	To trace the variation of F	
STEP V	To trace the variation of M	

STEP I. *Variation of* K′, K″. (Observe that these are always negative, and that l, K stand for l_1, K′ or l_2, K″ as the case may be.)

1° *Segment* $A_1P = x_1$ *loaded*, $K = \frac{w x_1^2}{12l}(x_1^2 - 2l^2) = -\frac{w}{12l}\left\{l^4 - (l^2 - x_1^2)^2\right\}$. (93*a*)

2° *Segment* $BP = x_2$ *loaded*, $K = -\frac{w}{12l}(l^2 - x_1^2)^2 = -\frac{w}{12l}\left\{l^2 - (l - x_1)^2\right\}^2$. (93*b*)

In both cases it is clear that −K increases (with x_1, x_2 respectively, *i. e.*,) with the extension of the Load, and is a maximum when $x_1 = l$, or $x_2 = l$, *i. e.*, when the Span is fully loaded, *i. e.*, when $K = -\frac{1}{12} w l^3$.

STEP II. *Variation of* M_2. By Results (22), (30),

$$2 M_2 (l_1 + l) = 3 (K' + K''), \qquad M_2 = 3 (K' + K'') \div (l_1 + l_2) \qquad (94)$$

∴ $-M_2$ increases with the Load, and is a maximum when l_1, l_2 are both fully loaded.

STEP III. *Variation of* R'_1, R''_1, R'_2, R''_2. It is easily seen that that R'_1, R''_1, R'_2, R''_2 increase with the Load on l_1, l_2, respectively, and are always +.

By (30, 31), $R''_1 = R''_1 - \frac{M_2}{l_1}$, $R'_2 = R'_2 - \frac{M_2}{l_2}$, of which $-M_2$ is always + and increases with the Load.

∴ R''_1, R'_2 are always + and increase with the Load, (95)

By (30, 31), $R'_1 = R'_1 + \frac{M_2}{l_1}$, $R''_2 = R''_2 + \frac{M_2}{l_2}$. As M_2 is always −, it is clear that R'_1, R''_2 may be either ±. It will suffice to trace the variation of R'_1.

By (30), $R'_1 = R'_1 + \frac{3(K' + K'')}{2l_1(l_1 + l_2)}$, (*see* Rankine's Civil Engineering, Art. 161,

Ex VII for R_1', and Art 8 of this Paper for K', K'') The two cases of Load on A_1P or A_2P require separate consideration

CASE (1) Segment $A_1P = x_1$ *loaded*

$$R'_1 = \frac{w x_1 (2l_1 - x_1)}{2l_1} - \frac{w x_1^2 (2l_1^2 - x_1^2)}{8l_1^2 (l_1 + l_2)} + \frac{3 K''}{2l_1 (l_1 + l_2)}$$

$$= w \frac{l_1^2 - (l_1 - x_1)^2}{2l_1} - w \frac{l_1^4 - (l_1^2 - x_1^2)^2}{8 l_1^4 (l_1 + l_2)} + \frac{3K''}{2l_1 (l_1 + l_2)} \qquad (96a),$$

of which the two first terms (together) may be shown to be essentially + and increasing with x_1 ($x_1 < l_1$), and the last −

CASE (2) *Segment* $A_2P = x_2$ *loaded*

$$R'_1 = \frac{w x_2^2}{2l_1} - \frac{w x_2^2 (2l_1 - x_2)^2}{8l_1 \ (l_1 + l_2)} + \frac{3K''}{2l_1 (l_1 + l_2)}$$

$$= \frac{w x_2^2}{2l_1} \left\{ 1 - \frac{(2l_1 - x_2)^2}{4l_1 (l_1 + l_2)} \right\} + \frac{3K''}{2l_1 (l_1 + l_2)} \qquad (96b)$$

of which the first term is essentially + and increasing with x_2, and the last is −

Combining these Results, it follows that —

(a) "R'_1 is a negative max when l_1 is unloaded and l_2 fully loaded",
(b) "R'_1 increases with + sign with extension of the Load on l_1, and is a positive max when l_2 is unloaded and l_1 fully loaded", (97)

Similar Results obtain *mutatis mutandis* in the case of R''_2

STEP IV *Variation of* F It may now be shown* by elementary considerations that F attains its greatest value ($\mathbf{F}$) on the span l_1 *when the longer segment of that span is covered* as follows —

(1) *Greatest positive value* (near Support A_1) when the longer segment A_2P ($= x''$) is fully loaded, and l_2 unloaded

$$\mathbf{F} = R'_1 = \frac{w x''^2}{2l_1} \left\{ 1 - \frac{(2l_1 - x'')^2}{4l_1 (l_1 + l_2)} \right\} \qquad (98)$$

(2) *Greatest Negative value* (near Support A_2) when the longer segment A_1P ($= x'$) and also the other span (l_2), are fully loaded

$$\mathbf{F} = -R''_1 = -\left\{ R''_1 - \frac{3 (K' + K'')}{2 l_1 (l_1 + l_2)} \right\}$$

$$= -\left\{ w \frac{x'^2}{2l_1} + \frac{w x'^2 (2 l_1^2 - x'^2)}{8 l_1^2 (l_1 + l_2)} + \frac{w l_1^3}{8 (l_1 + l_2)} \right\}$$

$$= -\frac{w x'^2}{2l_1} \left\{ 1 + \frac{(2 l_1^2 - x'^2)}{4 l_1 (l_1 + l_2)} \right\} - \frac{w l_1^3}{8(l_1 + l_2)} \qquad (99)$$

Similar Results obtain *mutatis mutandis* on the other span (l_2), remembering especially to change the sign of $\mathbf{F}$ from ± to ∓ according to the usual convention of the sign of a Shearing Force

[The graphic representation of $\mathbf{F}$ is given† in *Plate* XIX by the (chain-dotted) lines $F_3 A_2$ and $F_2 F_1$ for the span l_1, and by $F_2 A_2$ and $F_3 F_1$ for the span l_2]

STEP V *Variation of* M It may now be shown* by elementary considerations that M attains its greatest value $\mathbf{M}$ *at every section* on the span l_1 as follows —

(1) *Greatest Positive value*, (near Support A_1) when l_2 is unloaded and l_1 loaded,

* Similar to those of Art 813, of Rankine's Applied Mechanics

† For case of equal Spans ($l_1 = l_2$)

$$\mathbf{M} = R'_1 x' - w\frac{x'^2}{2} = \tfrac{7}{8}\ ncx' - w\frac{x'^2}{2} \tag{100}$$

$$\mathbf{M}_{0,1} = \frac{1}{2w} R'^2_1 = \tfrac{7}{128} wc^2, \text{ where } x' = \tfrac{7}{8} c \tag{101}$$

(2) *Greatest Negative value*, (near Support A_1) when l_2 is loaded and l_1 unloaded

$$\mathbf{M} = R'_1 x' = -\tfrac{1}{8} wcx', \tag{102}$$

(3) *Greatest Negative value*, (near Support A_2) when both Spans are fully loaded

$$\left.\begin{aligned}\mathbf{M} &= \frac{x'}{l} M_2 + M = -\frac{w}{2}(c - x'')^2 + \tfrac{1}{4}\ wcx'', \\ \mathbf{M}_m &= -\tfrac{1}{8} wc^2 \text{ at Support } A'',\end{aligned}\right\} \tag{103}$$

Similar Results obtain *mutatis mutandis* on the other span l

[The graphic representation of $\mathbf{M}$ is given* in *Plate* XIX, by $A_1 M_3$ I and $A_1 e_1 M_1$ for the span l_1, and by $A_3 M_2$ I and $A_3 e_3 M_1$ for the Span l_2]

Ex 13 *Three-Span Symmetric Beam under uniform moving Load* The investigation of this case will be very briefly given—($l_1 = l_3 = l$)

STEP i As in *Ex* 12, $K = -\frac{1}{12} wl^3$ at a maximum

STEP ii From the values of M_2, M_3 in *Ex* 5, it is easily seen that

$$\left.\begin{aligned}&\text{“} -M_2, -M_3 \text{ are maxima when } w_3 = 0, w_1 = 0, \textit{respectively} \\ &\text{and the other spans fully loaded”,}\end{aligned}\right\} \tag{104a}$$

$$\left.\begin{aligned}&\text{“} + M_2, + M_3 \text{ are maxima when } w_1 = 0, w_2 = 0\ ,\ w_3 = 0, \\ &w_2 = 0 \text{ respectively, and the remaining side span fully loaded”,}\end{aligned}\right\} \tag{104b}$$

STEP iii *Variation of* R'_1, R''_1 &c

$$R'_1 = R'_1 + \frac{M_2}{l} = \tfrac{1}{2} w_1 l + \frac{M_2}{l}, R''_3 = \tfrac{1}{2} w_3 l + \frac{M_3}{l} \tag{105}$$

From (83), it may now be shown that—

“R'_1, R''_3 are maxima when $w_2 = 0$, and l_1, l_3 are fully loaded”, (106)

$$R''_1 = \tfrac{1}{2} w_1 l - \frac{M_2}{l}, R'_3 = \tfrac{1}{2} w_3 l - \frac{M_3}{l} \tag{107}$$

From (83), it may now be shown that—

$$\left.\begin{aligned}&\text{“} R''_1, R'_3 \text{ are maxima when } w_3 = 0, w_1 = 0, \textit{respectively,} \\ &\text{and the remaining spans fully loaded”,}\end{aligned}\right\} \tag{108}$$

$$R'_2 = R'_2 + \frac{M_3 - M_2}{l_2}, R''_2 = R''_2 + \frac{M_2 - M_3}{l_2} \tag{109}$$

From (83), it may now be shown that—

$$\left.\begin{aligned}&R'_2, R''_2 \text{ are maxima when } w_3 = 0, w_1 = 0, \textit{respectively}, \text{ and the} \\ &\text{remaining spans fully loaded”,}\end{aligned}\right\} \tag{110}$$

STEP iv *Variation of* F By considerations similar to those of *Ex* 12, it may now be shown that F attains its Greatest Value ($\pm$ **F**) in any Span when one or other of the Segments x', x'' extending up to the Section *is fully loaded*, (and the other x'' or x', unloaded), and the remaining Spans so loaded as to give the Reaction at the end of the unloaded segment its greatest value—(according to the Results in Step iii).

[The above Statement is obviously a perfectly general Result applicable to all Cases]

STEP v *Variation of* **M** By considerations quite similar to those of *Ex* 12,

* For case of equal Spans ($l_1 = l_2$)

It may now be shown that M attains its Greatest Value (**M**) *at every section* in each span as follows —

SPANS	LOAD DISTRIBUTION WHICH PRODUCES	
	Greatest + Bending Moment	Greatest − Bending Moment
Side Spans (not near Piers)	Side Spans loaded Centre Span empty	Centre Span and further Side Span loaded Remaining Span empty
Over and near Piers	None	Two Spans meeting at Pier loaded Remaining Span empty
Centre Span (not near Piers)	Centre Span loaded Side Spans empty	Side Spans loaded Centre Span empty

Plate XX shows the Diagrams of Shearing Force and Bending Moment of a continuous Uniform Beam of three equal Spans, under the five different distributions of Uniform Load which produce the GREATEST ± BENDING MOMENT (± **M**) at some part or other of the Beam This sufficiently illustrates the above principles It has not been thought necessary to exhibit the GREATEST SHEARING FORCE (**F**)

A numerical Example is here added to illustrate the principles and formulæ of this Paper

Ex 14 *Pennair Bridge*, (Madras Railway) This Bridge is borne on Continuous Girders of I-section of two equal (64′) Spans

Notation A_t, A_c the cross-sectional areas of tension and compression flanges

A_s the cross sectional area in shear (of Web)

A the whole area of cross section $= A_t + A_s + A_c$

p_t, p_c, p_s the max tensile compressive, and shearing stress intensities in a cross section

y_t y_1, the distances of the "neutral axis" of cross section from its convex and concave edges

d' the effective depth of cross section

*Data** $l_1 = 64' = l$, $d' = 45''$

Cross-section symmetrical,—Over Pier, $A_t = 23$ *sq in* $= A_c$, $A_s = 17$ *sq in*

In Side spans, $A_t = 18$ *sq in* $= A_c$, $A_s = 17$ *sq in*

Dead Load, $w' = 3\ 5$ cwt per ft run, *Moving Load* $w'' = 10$ cwt per ft run

Find maximum maximorum and permanent maximum longitudinal and shearing stress-intensities

Solution By the well known expression for "Moment of Resistance", $\mathfrak{M} = \frac{p_c}{y_c}\ I$, or $\frac{p_t}{y_t}\ I$

And in a symmetrical cross section $y_t = \frac{d'}{2} = y_c$

* The Data are taken from No CCLX, of "Professional Papers on Indian Engineering", [First Series]

$\therefore p_t$ or $p_c = \dfrac{d'}{2} \cdot \dfrac{\mathfrak{M}}{I} = \dfrac{d'}{2} \cdot \dfrac{M}{I}$ by the 'equation of moments'

And* in an **I** section, $I = d'^2 \left(\dfrac{A_s}{12} + \dfrac{(A_t + A_c) A_s + 4 A_t A_c}{4A} \right)$

But in a symmetric cross section, $A_t = A_c$, and $A = 2A_t + A_s$

Hence on reduction, $I = \dfrac{d'^2}{12}\left(A_s + 6A_t \right)$

And p_c or $p_t = \dfrac{6\,M}{d'\,(A_s + 6A_t)}$ in general,

$\therefore p_c$ or $p_t = \dfrac{6\,M}{45\,(17 + 6 \times 23)} = \dfrac{M}{1162.5}$ over Pier,

$= \dfrac{6\,M}{45\,(17 + 6 \times 18)} = \dfrac{M}{937.5}$ in Side-Spans

And by what precedes it appears that—

"M_2, F'_2 are greatest, or become M_o, F''_1, F'_o over the Pier when both Spans are loaded", in which case $w_1 = w = 13.5$ *cwt per ft run* $= w_2$

$\therefore M_2 = -\frac{1}{8} w_1 c^2 = -\frac{1}{8} \times 13.5 \times 32^2 = -6912$ *ft cwt* $= -82944$ *inch cwt*

$-F''_1 = F'_2 = R''_1 = \frac{5}{4} w_1 c = \frac{5}{4} \times 13.5 \times 32 = 540$ *cwt*

Also "$M_{0,1}$, F'_1 are greatest, or become $M_{0,2}$, F'_1 when l_1 is loaded, and l_2 empty", in which case $w_1 = 13.5$ *cwt per ft run*, $= w$,

$\therefore -F''_2 = F'_1 = R'_1 = \dfrac{7w_1 - w_2}{16}\, l = \dfrac{7 \times 13.5 - 3.5}{16}\, l = 364$ *cwt*

$M_{0,2} = M_{0,1} = \dfrac{1}{2w_1} R'^2_1 = \dfrac{(364)^2}{2 \times 13.5} = 4907.26$ *ft cwt* $= 58887.1$ *inch cwt*

and occur at distances $= \dfrac{R'_1}{w_1} = \frac{364}{13.5} = 27'$ from outer Supports (A_1, A_3)

Hence the maximum maximorum longitudinal stress-intensities are

p_t or $p_c = \frac{82944}{1162.5} = 71.4$ *cwt per sq in* over Pier,

p_c or $p_t = \frac{58887.1}{937.5} = 63$ *cwt per sq in* in side spans at 27' from Pier

And the maximum maximorum shearing stress-intensities are

$p_s = \frac{540}{17} = 31.8$ *cwt per sq in* over Pier,

$p_s = \frac{364}{17} = 21.4$ *cwt per sq in* at Abutments

The permanent maximum stress intensities are due to the Steady Load alone, in which case $w_1 = 3.5$ *cwt per foot run* $= w_2$

$M_2 = -\frac{1}{8} w_1 c^2 = -\frac{1}{8} \times 3.5 \times 32^2 = 1792$ *ft cwt* $= 21504$ *inch cwt*

$-F''_1 = F'_o = R''_1 = \frac{5}{4} w_1 c = \frac{5}{4} \times 3.5 \times 32 = 140$ *cwt*

$-F''_2 = F'_1 = R'_1 = \frac{3}{4} w_1 c = \frac{3}{4} \times 3.5 \times 32 = 84$ *cwt*

$M_{0,2} = M_{0,1} = \dfrac{1}{2w_1} R'^2_1 = \dfrac{84^2}{2 \times 3.5} = 1008$ *ft cwt* $= 12096$ *inch-cwt*

And the permanent maximum stress intensities are—

$$\textit{Longitudinal}, \begin{cases} p_t \text{ or } p_c = \dfrac{21504}{1162.5} = 18.5 \textit{ cwt per sq in} \\ p_c \text{ or } p_t = \dfrac{12096}{937.5} = 13 \textit{ cwt per sq in} \end{cases}$$

* Rankine's Civil Engineering, Art, 163, Ex IX.

Shearing, ... $\begin{cases} p_s = \dfrac{140}{17} = 8\ 2 \textit{ cwt per sq in} \\ p_s = \dfrac{84}{17} = 5 \textit{ cwt per sq in} \end{cases}$

As this Girder was brought into position *by rolling* from one end, it is advisable also to find the maximum stress-intensities due to this cause, these occur when half the Girder 64′ overhangs like a Cantilever loaded with its own weight only ($w = 2\ 75$ *cwt per ft run*, excluding superstructure)

Here $M_m = -\frac{1}{2} wl^2 = -\frac{1}{2} \times 2\ 75 \times 64^2 = -5632\,ft\ cwt = -67584$ *inch cwt*
$- F_m = R'' = 2\ 75 \times 64 = 176$ cwt

And the maximum stress intensities (of rolling) are—

Longitudinal, p_t or $p_c = \dfrac{67584}{1162\ 5} = 58$ *cwt per sq in*

Shearing, $p_s \quad = \dfrac{176}{17} = 10\ 4$ *cwt per sq in*

All these maximum stress-intensities are well within the working stress-intensities of good wrought-iron

The maximum Deflexion will occur under that arrangement of the Moving Load which produces positive maximum maximorum Bending Moment, in which case $w_1 = 13\ 5$ *cwt per foot run*, $w_2 = 3\ 5$ *cwt. per foot run*

The abscissa of the section of max Deflexion is given by the positive root, ($< l$) of Eq 62*a*, which gives—

$$\frac{x^3}{l^3} - \tfrac{8}{18}\left(9 + \tfrac{7}{27}\right)\frac{x^2}{l^2} + \tfrac{3}{8}\left(1 + \tfrac{7}{27}\right)\frac{x}{l} + \tfrac{1}{8}\left(1 - \tfrac{7}{27}\right) = 0$$

The value $\dfrac{x}{l} = 5378$ will be found to satisfy this nearly The maximum Deflexion is then given by Result (63*a*),

$$\delta = \frac{w_1 c^4}{EI}\left\{12\frac{x^4}{l^4} - \frac{500}{27}\frac{x^3}{l^3} + \frac{84}{9}\frac{x^2}{l^2}\right\}$$

$$= \frac{\frac{13\ 5 \times 112}{12} \times (32 \times 12)^4 \times (-2\ 711)}{24000000 \times \frac{(45)^2}{12} \times (17 + 6 \times 18)} \begin{cases} \text{reducing all units to inches and lbs} \\ \quad\text{and taking } E = 24000000 \text{ lbs per} \\ \quad\text{sq inch} \end{cases}$$

$= -\ 708''$, and occurs at $588 \times 64' = 34'\ 4$ from the Pier

Again, when the Moving Load covers both Spans, the abscissa of the section of maximum Deflexion is by Result (72)

$x = 578\ l = 36'\ 8$ from the Pier,

and the Deflexion is by (73),

$$\delta = \frac{0867\ wc^4}{EI} = \frac{0867 \times \frac{13\ 5 \times 112}{12} \times (32 \times 12)^4}{24000000 \times \frac{(45)^2}{12} \times (17 + 6 \times 18)} = 47''$$

These Deflexions are both so small that it is not worth while calculating that due to the steady Load alone

[In the published official calculations about this Bridge, (No CCLX. of "Profes-

sional Papers on Indian Engineering, [FIRST SERIES]), these Deflexions have been altogether miscalculated They have been apparently assumed to be exactly the same as in an *ordinary* "Supported Beam," *i e*, one fulfilling the conditions ex-plained at end of Article 16,) of length equal to the portion between the inflexion and abutment This procedure causes an error of about 8′ in the position of the maximum Deflexion, and considerably under estimates its magnitude]

21 Fixed Beams, Fixed and Supported Beams —The FIXATION of one or both Ends of a "Supported Beam" may be defined to consist in *preventing* to a greater or less extent *the alteration of slope* at one or both ends of the 'neutral surface', which would [illegible] take place if simply supported at the ends With this definition, together with the explanations in Art 2, it must be clear that this effect is produced by the application of a certain Force together with a certain Couple at those ends which are said to be 'fixed', and that, therefore, the Cases of a (more or less perfectly) FIXED BEAM and of a FIXED AND SUPPORTED BEAM fall under the principles of this Paper, (*see* Result 3 of Art 2)

Thus a FIXED BEAM in general is precisely in the condition of the centre Span of a Three-Span Continuous Beam, and a FIXED AND SUPPORTED BEAM in general is precisely in the condition of either Span of a Two-Span Continuous Beam

Ex 15 A Fixed Uniform Beam *under uniform load* is precisely in the condition of the centre Span of the uniformly loaded Symmetric Three Span Uniform Beam of Ex 4 of this Paper

It will suffice to make $l_1 = 0$, $l_3 = 0$, in the Results of that Example to make it applicable to this Case

Ex 16 A Fixed and Supported Uniform Beam *under uniform load* is precisely in the condition of either Span of the uniformly loaded Two-Span Uniform Beam (with equal Spans) of Ex 3 of this Paper

It will suffice to make either $l_1 = 0$, or $l_2 = 0$, in the Results of that Example to make it applicable to this Case

22 Fixed Continuous Beams —In all the applications made up to this point it has been supposed that the Beams were *simply supported* (Art 13) *at the extreme ends*, which at once assigned the values of the Moments ($M_1 = 0$, $M_{n+1} = 0$) of the Re-action-Couples at the ends

The Case of a Beam (more or less perfectly) *fixed at the Ends* may also be solved by the principles of this Paper, *if definite values be assigned* to these Moments (M_1, M_{n+1}) of the Re-action-Couples which cause the fixation The solution would, of course, require to be taken by solving the system of $(n - 1)$ Equations of Three Moments *de novo*, as the actual

values of the Re-action-Moments, and Shear-Re-actions are usually altered throughout by this alteration of M_1, M_{n+1}

But if the Fixation of the Ends be simply described as 'perfect', the values of M_1, M_{n+1} would require special determination by the consideration that they must be *such as to render the slope at the Ends zero* To do this, however, the integration of the Elastic Curve should be performed anew, as the condition must be introduced during the integration The Case is, however, hardly of sufficient importance to require special development here

22a. *Fixation of intermediate Supports* —It was explained (Art 10) that the Theorem of Three Moments is applicable only to *pairs of Spans which are simply supported at the common Support* It is in fact applicable to *any* such pair of Spans

The Case of a Beam (more or less perfectly) fixed *at any of its Supports* may be treated by the principles of this Paper, *if definite values be assigned* to the Moments of the Re-action-Couples which cause the fixation at those Supports the Theorem of Three Moments may then be applied to determine the remaining Re-action-Couples

Again if the fixation at any Support be 'perfect' the value of the Moment of the Re-action-Couple at that Support must be found by introducing into the equation of the Elastic Curve the condition that the slope (i) of the 'neutral surface' at that Support is to be zero

But this Case is not of sufficient importance to require development here

23 Restriction to Uniform Beams.—It will be seen that all the worked Examples of this Paper depend ultimately on the Theorem of Three Moments, and are therefore *applicable only to Uniform Beams* A BEAM OF UNIFORM STRENGTH cannot therefore with any real propriety be designed by the detailed Results of this Paper.

[The practice of many Engineers has been to take the Shearing Forces and Bending Moments assigned in this Paper, and design the Cross sections to suit them all along the Beam , it was supposed that this process would give a Beam of approximately UNIFORM STRENGTH But this gives a Beam of variable Section, and therefore violates the very first Step in the integration of the Elastic Curve (that in which "I" was taken to be constant throughout the Beam) It appears extremely doubtful whether a Beam so designed is really *a fair approximation* to one of Uniform Strength, except when the Weight of the Beam is small compared with the External Load

The proper course in design of a Beam of Uniform Strength would be to investigate the question *de novo,* introducing the condition of Uniform Strength into the

integration of the Elastic Curve *at the outset* This would completely change the form of the Results Its complete solution has not yet been discovered]

24 Economic Spans—The as yet solved cases of Continuous Beams being only those of UNIFORM SECTION, the scantling is of course really determined by that necessary solely for the

(*a*),—absolute maximum Bending Moment, M_m
(*b*),—absolute maximum Shearing Force, F_m

Now the latter (*b*) is almost always $>$ the corresponding quantity in *discontinuous* Spans, so that unless the former (*a*) be markedly less than the corresponding quantity in similar *discontinuous* Spans, there will be no advantage whatever in continuity.

Thus, comparing the Result of Ex 7 ($M_2 = -\frac{1}{2}wc^2$) with the well known Result for "Supported (discontinuous) Beams", ($M_m = \frac{1}{8}wl^2$) it is seen that,

"Continuity is disadvantageous in a Two Span Uniform Beam uniformly loaded", (111)

In determining scantling, the magnitude of M_m is however of much more importance than that of F_m And the absolute maximum Bending Moment (M_m) is—when the number of Spans exceeds two—usually less (*see* Ex 7—11) than in similar *discontinuous* Spans, so that there will be some advantage in continuity in such Cases

There is obviously—for a given Load—some arrangement of the Spans ($l_1, l_2, l_3,$) which makes the maximum Bending Moment less than any other, and this is—*cæteris paribus*—the most Economic arrangement.

To find this, observe that this quantity (M_m) is expressible as a function of the several loads ($w_1, w_2,$ &c) which are given, and of the several Spans ($l_1, l_2,$ &c , . .), the sum of the Spans ($l_1 + l_2 +$ &c) is of course a given quantity, hence their ratios are to be determined so as to make M_m a maximum, a problem usually solvible by the principles of Infinitesimal Calculus

Ex Uniformly loaded Symmetric Three-Span Beam ($l_1 = l_3, w_1 = w_2 = w_3$)

By (75), $M_m = M_2 = -\frac{w}{4}\,\frac{l_1^3 + l_2^3}{2l_1 + 3l_2}$, and $2l_1 + l_2 =$ constant.

Hence the minimum of M_m is given by—

$$\frac{d}{dl_1}\,\frac{l_1^3 + l_2^3}{2l_1 + 3l_2} = 0\text{ , and } 2 + \frac{dl_2}{dl_1} = 0$$

whence on reduction $10l_1^3 + 9l_1^2 l_2 - 12l_1^3 - 14l_2^3 = 0$

$$\text{or } \left(\frac{l_1}{l_2}\right)^3 + 9\left(\frac{l_1}{l_2}\right)^2 - 12\frac{l_1}{l_2} - 14 = 0$$

from which it will be found (on trial) that $l_1 = 1\,164\, l_2 = l$,

This arrangement of Spans is therefore the most economical

[This differs so little from equal Spans that the saving is of course very small thus it may be shown that, (if L = sum of Spans),

1° *Economic Spans, (continuous)*, $M_m = -\ 0109\, wL^2$
2° *Equal Spans, (continuous)* $M_m = -\ 0111\, wL^2$
3° *Equal Spans, (discontinuous)*, $M_m = +\ 0139\, wL^2$]

25 *Economy of uniformly loaded continuous equal Spans*—It was shown (Art 24) that in UNIFORM BEAMS the economy is in strictness limited to that due to the reduction of the absolute maximum Bending Moment (M_m) from its value in a discontinuous Span The proportionate reduction is shown in following Table —

BEAM		Reference	Value of M_m	Proportionate Reduction of M_m
Discontinuous Spans, .			$+\frac{1}{8} wc^2$	
CONTINUOUS UNIFORM BEAM	Two equal Spans, .	*Ex* 7, Art 19,	$-\frac{1}{8} wc^2$	None
	Three equal Spans, ..	*Ex* 8, Art 19,	$-\frac{1}{10} wc^2$	$\frac{1}{5}$ $(\frac{1}{8} wc^2)$
	Four equal Spans, .	*Ex* 9, Art 19,	$-\frac{3}{28} wc$	$\frac{1}{7}$ $(\frac{1}{8} wc^2)$
	Five equal Spans,	*Ex* 10, Art 19,	$-\frac{8}{76} wc^2$	$\frac{3}{19}$ $(\frac{1}{8} wc^2)$
	Six equal Spans,	*Ex* 11, Art 19,	$-\frac{11}{104} wc^2$	$\frac{2}{13}$ $(\frac{1}{8} wc^2)$

26 Advantages of Continuity.—This Paper shows that *the general effect* of Continuity over the Supports is the shifting of the sections of maximum Bending Moment to the Supports which is usually accompanied by a reduction of the magnitude of that maximum Bending Moment, and therefore, also by a reduction of the maximum (longitudinal) Stress-intensity, and maximum Deflexion

This is clearly *in general* attended with great advantage as far as economy of materials is concerned, especially in expensive material like iron

This advantage is usually greatest—(1) with symmetrical cross-sections (*i e*, cross-sections alike above and below), and (2) with Steady Load. These conditions deserve careful attention because in some cases Continuity is positively disadvantageous

Thus, observing, that Continuity causes opposite curvatures in parts of

the same Beam, and that under Moving Load this curvature varies, and is liable to be reversed, it is clear that a Continuous Beam must be suited (even under Steady Load) to act in parts as a CANTILEVER and in parts as a SUPPORTED BEAM, and within certain regions (under Moving Load) to act as either alternately.

Hence in a Continuous Flanged Girder different parts *of the same* Flange are in Tension and Compression, and under Moving Load certain parts of each Flange, as well as certain parts of the Bracing or Web are alternately in Tension and Compression. It follows that—

"A Continuous Uniform Beam is seldom advantageous

(*a*), with Cross-sections of Equal Strength,
(*b*), in Cast iron,
(*c*), with heavy moving Load", (112)

It is also usually considered that there is little* advantage in Continuity in Short Spans under 150 feet.

A C

* Stoney's Theory of Strains, Art. 258.

No CXC.

TABLES OF RAJBAHA VELOCITIES AND DISCHARGES FOR SIDE SLOPES 1 TO 1

Computed for the Punjab Irrigation Department, under superintendence of CAPT ALLAN CUNNINGHAM, R E, *Hony Fell of King's Coll Lond*

THESE Tables have been computed from the following data and formulæ —

Data,—	*Required,—*
Channel, earthen	A = Area *in square feet*
Section, trapezoidal	R = Hydraulic Mean Depth *in feet*
Side-slopes, 1 to 1, or 45°	V = Mean Velocity *in feet per second*
b = bed-width *in feet*	D = Discharge *in cubic feet per second*
d = depth of water *in feet*	C = Co-efficient in formula $V = C\ \sqrt{RI}$
f = fall of channel in 5,000 feet *in feet*	

Formulæ used in computation

$$A = (b + d)\ d, \qquad R = \frac{A}{b + 2\ 828d}$$

$$V = \frac{2R}{\sqrt{7 + 1\ 7066\ R}}\ \sqrt{f}, \qquad D = A\ V$$

$$C = \frac{1}{\sqrt{00008533 + \frac{00035}{R}}}$$

The formula for V is modified (to a form suited for computation in Tables) from one given in the "Professional Papers on Indian Engineering", [First Series], No CXCVII, (by the late Lieut Col J C Anderson, R E), 4th type of Table I,

$$\frac{RI}{U^2} = 00035\ (2438 + \frac{1}{R})$$

as *suitable for channels whose "Bed and sides are of earth"* This formula in simply adapted to English measures from that given by M Bazin in his "Récherches Expérimentales sur l' écoulement de l'eau dans les canaux découverts"

The Coefficient C (which forms the last column of the Tables) is simply the square root of the reciprocal of 00035 $\left(2438 + \frac{1}{R}\right)$, so that $U = C\ \sqrt{RI}$, whence also

$$V = C\ \sqrt{R\frac{f}{5000}}, \text{ or } = C\ \sqrt{RI}.$$

[These Tables have been prepared throughout by two* independent computers The numbers in the columns of "Areas" are *exact* The numbers in the columns of R, V, D, C were in every case computed to at least one more decimal than is now printed, and the first differences were examined by the Author himself

From the fair regularity of these differences, it is believed that the last figure does not err by more than 2 in any column] A C

* Pandit Chhote Lál and Lálá Gangá Saháy, Asst Masters in the Thomason C E College

RAJBAHA VELOCITIES AND DISCHARGES—SIDE SLOPES 1 TO 1

Bed Width	Area of water section.	Mean Hydraulic depth.	Fall of Channel in 5,000 feet: 2 00 V	2 00 D	1 75 V	1 75 D	1 50 V	1 50 D	1 25 V	1 25 D	1 00 V	1 00 D	0 75 V	0 75 D	0 50 V	0 50 D	0 25 V	0 25 D	Co-efficient C
			Depth of water, 1 0 foot																
3	4 00	686	679	2 72	635	2 54	588	2 35	537	2 15	480	1 92	416	1 66	340	1 36	240	960	40 99
4	5·00	·732	721	3·61	675	3 37	·625	3 12	570	2 85	510	2 55	442	2 20	361	1 80	255	1 28	42·13
5	6·00	766	752	4 51	704	4 22	651	3 91	595	3·57	532	3 19	461	2 76	376	2 26	266	1 60	42 95
6	7·00	793	776	5 43	726	5 08	·672	4 70	613	4 29	549	3 84	475	3 33	388	[illegible] 72	274	1 92	43 58
7	8 00	814	795	6·36	744	5 95	688	5 51	628	5·03	562	4 50	487	3·89	398	3 18	281	2 25	44 05
8	9 00	·831	810	7 29	758	6 82	702	6 32	641	5 77	573	5 16	496	4 47	405	3 65	286	2 58	44 44
9	10·00	845	823	8·23	770	7 70	713	7 13	651	6 51	582	5 82	504	5 04	411	4 11	291	2 91	44 75
10	11 00	858	834	9 17	780	8 58	722	7 94	659	7 25	590	6 48	511	5 62	417	4 59	295	3 24	45 02
11	12 00	868	843	10·11	788	9 46	730	8 76	666	8 00	596	7 15	516	6 19	421	5 06	298	3 57	45 24
12	13 00	877	850	11·06	·796	10·34	737	9 58	673	8 74	602	7 82	521	6 77	425	5 53	301	3 91	45 43
13	14 00	885	858	12 01	802	11·23	·743	10 40	678	9·49	606	8 49	525	7 35	429	6 00	303	4 24	45 60
14	15 00	·891	864	12·95	808	12 12	748	11 22	683	10 24	611	9 16	529	7 93	432	6·48	305	4 58	45 75
15	16·00	897	869	13 90	813	13 01	753	12·04	687	10 99	·615	9 83	532	8 51	434	6 95	307	4 92	45 87
16	17 00	903	874	14 85	817	13 90	757	12 86	691	11 74	618	10 50	535	9 10	437	7 43	309	5 25	45 98
17	18·00	908	878	15 81	821	14 78	760	13 69	694	12 50	621	11 18	538	9 68	439	7 90	310	5 59	46 09
18	19·00	912	·882	16 76	825	15 68	764	14 51	697	13 25	624	11·85	540	10 26	441	8 38	312	5 92	46 18
19	20 00	916	885	17 71	828	16 57	767	15 34	700	14 00	626	12 52	542	10 84	443	8 86	313	6 26	46·26
20	21 00	·920	889	18 66	831	17 46	770	16·16	703	14 75	628	13 20	544	11 43	444	9 33	314	6 60	46 34

RAJBAHA VELOCITIES AND DISCHARGES—SIDE SLOPES 1 TO 1

Bed Width	Area of water section.	Mean Hydraulic depth	Fall of Channel in 5,000 feet																Co-efficient C
			2 00		1 75		1 50		1 25		1 00		0 75		0 50		0 25		
			V	D	V	D	V	D	V	D	V	D	V	D	V	D	V	D	
Depth of water, 1 5 feet																			
3	6.75	932	899	6.07	841	5.68	779	5.26	711	4.80	636	4.29	551	3.72	450	3.04	318	2.15	46.58
4	8.25	1.000	959	7.92	897	7.40	831	6.85	758	6.26	678	5.60	588	4.85	480	3.96	339	2.80	47.95
5	9·75	1.054	1.01	9.81	941	9.17	871	8.49	795	7.75	711	6.93	616	6.01	503	4.90	356	3.47	48.97
6	11.25	1.098	1.04	11.73	976	10.97	903	10.16	824	9.28	737	8.30	639	7.18	521	5·87	369	4.15	49.76
7	12.75	1.134	1.07	13.68	1.00	12.79	929	11.85	848	10.82	759	9.68	657	8.38	537	6.84	379	4.84	50.38
8	14.25	1.164	1.10	15.65	1.03	14.64	942	13.55	869	12.37	777	11.08	673	9.59	550	7.83	381	5.54	50·90
9	15.75	1.189	1.12	17.63	1.05	16.49	970	15.27	885	13.93	792	12.47	·686	10.80	560	8.82	396	6.23	51.33
10	17.25	1.211	1.14	19.63	1.06	18.35	985	17.00	899	15.52	804	13·88	697	12·02	569	9.81	402	6·94	51.69
11	18.75	1.230	1.15	21.63	1.08	20.23	999	18.73	912	17.10	816	15.29	706	13.24	577	10·81	408	7.65	52.00
12	20·25	1.246	1.17	23.64	1.10	22.11	1.01	20.47	923	18.69	825	16.71	715	14.47	584	11.82	413	8·35	52.27
13	21.75	1.261	1.18	25.65	1.10	23.99	1·02	22.21	932	20.28	834	18.14	722	15.71	590	12.83	417	9.07	52.51
14	23.25	1.275	1.19	27.67	1.11	25.88	1.03	23.96	941	21.87	842	19.57	729	16.94	595	13.84	421	9.78	52.71
15	24.75	1.286	1.20	29.69	1.12	27.77	1.04	25.71	948	23.47	848	21.00	735	18.18	600	14.85	424	10.50	52.89
16	26.25	1.297	1.21	31.72	1·13	29.67	1.05	27.47	955	25.08	854	22.43	740	19.42	604	15·86	428	11.22	53.06
17	27.75	1.306	1.22	33.75	1.14	31.57	1.05	29.23	962	26.68	860	23.87	745	20·67	608	16.88	430	11.93	53.19
18	29.25	1.315	1.22	35.78	1.14	33.47	1.06	30·99	967	28.29	865	25.30	749	21.91	612	17·89	433	12.65	53.34
19	30.75	1.323	1.23	37.82	1.15	35.37	1.07	32.75	972	29·90	870	26·74	753	23.16	615	18.91	435	13.37	53.46
20	32.25	1.330	1.24	39·85	1.16	37.28	1.07	34.52	977	31.51	874	28.18	757	24.41	618	19.93	437	14.09	53.57

RAJBAHA VELOCITIES AND DISCHARGES—SIDE SLOPES 1 TO 1

Bed Width	Area of water section,	Mean Hydraulic depth	Fall of Channel in 5,000 feet																Co efficient C
			2.00		1.75		1.50		1.25		1.00		0.75		0.50		0.25		
			V	D	V	D	V	D	V	D	V	D	V	D	V	D	V	D	
Depth of water, 2 feet																			
3	10.00	1.155	1.09	10.91	1.02	10.20	.945	9.45	.862	8.62	.771	7.71	.668	6.68	.545	5.45	.386	3.86	50.75
4	12.00	1.243	1.16	13.96	1.09	13.06	1.01	12.09	.920	11.04	.823	9.88	.713	8.55	.582	6.98	.412	4.94	52.20
5	14.00	1.314	1.22	17.11	1.14	16.01	1.06	14.82	.966	13.53	.864	12.10	.749	10.48	.611	8.56	.432	6.05	53.32
6	16.00	1.373	1.27	20.32	1.19	19.01	1.10	17.60	1.00	16.07	.898	14.37	.778	12.44	.635	10.16	.449	7.18	54.21
7	18.00	1.422	1.31	23.58	1.23	22.06	1.13	20.42	1.04	18.64	.926	16.68	.802	14.44	.655	11.79	.463	8.34	54.93
8	20.00	1.464	1.34	26.87	1.26	25.13	1.16	23.27	1.06	21.24	.950	19.01	.823	16.46	.672	13.44	.475	9.50	55.53
9	22.00	1.501	1.37	30.20	1.28	28.25	1.19	26.16	1.09	23.88	.971	21.36	.841	18.50	.687	15.10	.485	10.68	56.04
10	24.00	1.533	1.40	33.56	1.31	31.39	1.21	29.06	1.11	26.53	.989	23.73	.856	20.55	.699	16.78	.494	11.86	56.47
11	26.00	1.561	1.42	36.92	1.33	34.54	1.23	31.98	1.12	29.19	1.00	26.11	.870	22.61	.710	18.46	.502	13.05	56.84
12	28.00	1.586	1.44	40.51	1.35	37.70	1.25	34.91	1.14	31.87	1.02	28.50	.882	24.68	.720	20.15	.509	14.25	57.16
13	30.00	1.608	1.46	43.71	1.36	40.88	1.26	37.85	1.15	34.55	1.03	30.91	.892	26.76	.729	21.86	.515	15.46	57.45
14	32.00	1.628	1.47	47.12	1.38	44.07	1.28	40.81	1.16	37.25	1.04	33.32	.902	28.85	.736	23.56	.521	16.66	57.70
15	34.00	1.646	1.49	50.54	1.39	47.27	1.29	43.77	1.18	39.95	1.05	35.74	.910	30.95	.743	25.27	.526	17.87	57.94
16	36.00	1.662	1.50	53.96	1.40	50.48	1.30	46.74	1.19	42.66	1.06	38.16	.918	33.04	.750	26.98	.530	19.08	58.14
17	38.00	1.677	1.51	57.40	1.41	53.69	1.31	49.71	1.19	45.38	1.07	40.59	.925	35.15	.755	28.70	.534	20.29	58.32
18	40.00	1.691	1.52	60.84	1.42	56.91	1.32	52.69	1.20	48.09	1.08	43.02	.931	37.26	.761	30.42	.538	21.51	58.49
19	42.00	1.703	1.53	64.29	1.43	60.13	1.33	55.67	1.21	50.82	1.08	45.46	.937	39.37	.765	32.14	.541	22.73	58.65
20	44.00	1.715	1.54	67.74	1.44	63.36	1.35	58.66	1.22	53.55	1.09	47.90	.943	41.48	.770	33.87	.544	23.95	58.78

RAJBAHA VELOCITIES AND DISCHARGES—SIDE SLOPES 1 TO 1

Bed Width	Area of water section	Mean Hydraulic depth	Fall of Channel in 5,000 feet: 2.00		1.75		1.50		1.25		1.00		0.75		0.50		0.25		Co efficient C
			V	D	V	D	V	D	V	D	V	D	V	D	V	D	V	D	
Depth of water, 2.5 feet																			
3	13.75	1.365	1.26	17.39	1.18	16.27	1.09	15.06	1.00	13.74	894	12.29	774	10.65	632	8.70	447	6.15	54.09
4	16.25	1.468	1.35	21.88	1.26	20.47	1.17	18.95	1.06	17.30	952	15.47	825	13.40	673	10.94	476	7.74	55.58
5	18.75	1.553	1.41	26.52	1.32	24.80	1.22	22.96	1.12	20.96	1.00	18.75	866	16.24	707	13.26	500	9.38	56.74
6	21.25	1.626	1.47	31.26	1.38	29.23	1.27	27.07	1.16	24.71	1.04	22.10	901	19.14	735	15.63	520	11.05	57.67
7	23.75	1.688	1.52	36.07	1.42	33.74	1.32	31.24	1.20	28.51	1.07	25.51	930	22.09	759	18.04	537	12.75	58.45
8	26.25	1.742	1.56	40.95	1.46	38.30	1.35	35.46	1.23	32.37	1.10	28.96	955	25.08	780	20.48	552	14.48	59.10
9	28.75	1.789	1.60	45.88	1.49	42.91	1.38	39.73	1.26	36.27	1.13	32.44	977	28.10	798	22.94	564	16.22	59.66
10	31.25	1.831	1.63	50.85	1.52	47.57	1.41	44.04	1.29	40.20	1.15	35.96	997	31.14	814	25.43	575	17.98	60.14
11	33.75	1.868	1.65	55.84	1.55	52.24	1.43	48.36	1.31	44.15	1.17	39.49	1.01	34.20	827	27.92	585	19.74	60.55
12	36.25	1.901	1.68	60.89	1.57	56.96	1.45	52.73	1.33	48.14	1.19	43.06	1.03	37.29	840	30.45	594	21.53	60.92
13	38.75	1.931	1.70	65.95	1.59	61.69	1.47	57.11	1.35	52.13	1.20	46.63	1.04	40.39	851	32.97	602	23.32	61.24
14	41.25	1.958	1.72	71.03	1.61	66.44	1.49	61.51	1.36	56.15	1.22	50.23	1.05	43.49	861	35.51	609	25.11	61.53
15	43.75	1.982	1.74	76.13	1.63	71.21	1.51	65.93	1.38	60.18	1.23	53.83	1.07	46.62	870	38.06	615	26.92	61.79
16	46.25	2.005	1.76	81.24	1.64	75.99	1.52	70.36	1.39	64.23	1.24	57.45	1.08	49.75	878	40.62	621	28.73	62.03
17	48.75	2.025	1.77	86.36	1.66	80.77	1.53	74.79	1.40	68.27	1.25	61.06	1.08	52.88	886	43.18	626	30.53	62.24
18	51.25	2.044	1.79	91.50	1.67	85.58	1.55	79.24	1.41	72.33	1.26	64.70	1.09	56.03	893	45.75	631	32.35	62.43
19	53.75	2.062	1.80	96.65	1.68	90.40	1.56	83.70	1.42	76.41	1.27	68.34	1.10	59.18	899	48.33	636	34.17	62.61
20	56.25	2.078	1.81	101.80	1.69	95.22	1.57	88.16	1.43	80.48	1.28	71.98	1.11	62.34	905	50.9	640	35.99	62.77

RAJBAHA VELOCITIES AND DISCHARGES—SIDE SLOPES 1 TO 1

Bed Width	Area of water section	Mean Hydraulic depth	Fall of Channel in 5,000 feet																Co efficient C
			2.00		1.75		1.50		1.25		1.00		0.75		0.50		0.25		
			V	D	V	D	V	D	V	D	V	D	V	D	V	D	V	D	
Depth of water, 3 feet																			
3	18.00	1.567	1.43	25.65	1.35	23.99	1.23	22.21	1.13	20.27	1.01	18.13	873	15.71	713	12.83	504	9.07	56.92
4	21.00	1.682	1.51	31.79	1.42	29.74	1.31	27.54	1.20	25.14	1.07	22.49	927	19.47	757	15.90	535	11.24	58.38
5	24.00	1.780	1.59	38.13	1.49	35.67	1.38	33.02	1.26	30.15	1.12	26.97	973	23.35	795	19.07	562	13.48	59.56
6	27.00	1.864	1.65	44.60	1.55	41.72	1.43	38.64	1.31	35.26	1.17	31.54	1.01	27.32	826	22.31	584	15.78	60.53
7	30.00	1.937	1.71	51.21	1.60	47.90	1.48	44.35	1.35	40.48	1.21	36.21	1.05	31.36	853	25.60	604	18.11	61.32
8	33.00	2.002	1.76	57.90	1.64	54.15	1.52	50.14	1.39	45.77	1.24	40.94	1.07	35.45	877	28.95	620	20.47	62.00
9	36.00	2.059	1.80	64.66	1.68	60.48	1.56	55.99	1.42	51.12	1.27	45.72	1.10	39.59	898	32.33	635	22.86	62.58
10	39.00	2.110	1.83	71.48	1.71	66.86	1.59	61.90	1.45	56.51	1.30	50.54	1.12	43.77	916	35.74	·648	25.27	63.09
11	42.00	2.156	1.87	78.36	1.75	73.29	1.62	67.86	1.48	61.95	1.32	55.41	1.14	47.99	933	39.18	660	27.70	63.54
12	45.00	2.197	1.90	85.28	1.77	79.77	1.64	73.85	1.50	67.42	1.34	60.30	1.16	52.22	948	42.64	670	30.15	63.94
13	48.00	2.234	1.92	92.24	1.80	86.28	1.66	79.88	1.52	72.92	1.36	65.23	1.18	56.49	961	46.12	679	32.61	64.29
14	51.00	2.268	1.95	99.23	1.82	92.82	1.69	85.94	1.54	78.45	1.38	70.17	1.19	60.77	973	49.62	688	35.08	64.60
15	54.00	2.299	1.97	106.26	1.84	99.40	1.70	92.02	1.56	84.00	1.39	75.14	1.21	65.07	·984	53.13	696	37.57	64.89
16	57.00	2.328	1.99	113.30	1.86	105.98	1.72	98.12	1.57	89.57	1.41	80.12	1.22	69.38	994	56.65	703	40.06	65.15
17	60.00	2.354	2.01	120.36	1.88	112.59	1.74	104.22	1.59	95.16	1.42	85.12	1.23	73.71	1.00	60.18	709	42.56	65.40
18	63.00	2.379	2.02	127.46	1.89	119.22	1.75	110.38	1.60	100.76	1.43	90.13	1.24	78.05	1.01	63.73	715	45.06	65.62
19	66.00	2.401	2.04	134.57	1.91	125.87	1.77	116.53	1.61	106.38	1.44	95.15	1.25	82.40	1.02	67.28	721	47.58	65.79
20	69.00	2.422	2.05	141.68	1.92	132.53	1.78	122.70	1.62	112.01	1.45	100.19	1.26	86.76	1.03	70.84	726	50.09	65.96

RAJBAHA VELOCITIES AND DISCHARGES—SIDE SLOPES 1 TO 1

Bed Width	Area of water section	Mean Hydraulic depth	Fall of Channel in 5,000 feet																Co efficient C
			2·00		1 75		1 50		1 25		1 00		0 75		0 50		0 25		
			V	D	V	D	V	D	V	D	V	D	V	D	V	D	V	D	
			Depth of water, 3 5 feet																
3	22 75	1 764	1 58	35 87	1 47	33 50	1 37	31 07	1 25	28 36	1 12	25 37	966	21 97	788	17·94	558	12 68	59 36
4	26 25	1 889	1 67	43 86	1 56	41·02	1 45	37 98	1 32	34·70	1 18	31 01	1 02	26 86	835	21 93	590	15 50	60 79
5	29 75	1 997	1 75	52 06	1 64	48 72	1 53	45 11	1 38	41 18	1 24	36 83	1 07	31 89	875	26 04	619	18 41	61 95
6	33 25	2 031	1 82	60 51	1 70	56 60	1 58	52 40	1 44	47 83	1 29	42 79	1 11	37 05	910	30 26	643	21 39	62 91
7	36 75	2 175	1 88	69 07	1 76	64 61	1 63	59·82	1 49	54 60	1 33	48 84	1 15	42 30	940	34 54	665	24 42	63 72
8	40 25	2 219	1 93	77 77	1 81	72 74	1·67	67 35	1 53	61 48	1 37	54 99	1 15	47 62	966	38 88	683	27 49	64 42
9	43 75	2 315	1 98	86 [illegible]	1 85	80 97	1 71	74 97	1 56	68 44	1 40	61 21	1 21	53 01	989	43 28	700	30 61	65 02
10	47 25	2 375	2 02	95 46	1 89	89 29	1 75	82 67	1 60	75 46	1 43	67 50	1 24	58 45	1 01	47 73	714	33 75	65 55
11	50 75	2 428	2 06	104 12	1 92	97 67	1 78	90 43	1 63	82 55	1 45	73 84	1 26	63 94	1 03	52 21	727	36 92	66·01
12	54 25	2 477	2 09	113 44	1 96	106 11	1 81	98 24	1 65	89 68	1 48	80 22	1 28	69 47	1 05	56 72	739	40 11	66 43
13	57 75	2 522	2 12	122 53	1 98	114 61	1 84	106·11	1 68	96 86	1 50	86 64	1 30	75 03	1 06	61 26	750	43 32	66 80
14	61 25	2 563	2 15	131 66	2 01	123 15	1 86	114 01	1 70	104 08	1 52	93 10	1 32	80 62	1 07	65 83	760	46 55	67 13
15	64 75	2 601	2 17	140 82	2 03	131 72	1 88	121 95	1 72	111 33	1 54	99 58	1 33	86 23	1 09	70 41	769	49 79	67 43
16	68 25	2 635	2 20	150 02	2 06	140 34	1 90	129 93	1 74	118 61	1 55	106 09	1 35	91 87	1 10	75 02	777	53 05	67 71
17	71 75	2 667	2 22	159 27	2 08	148 98	1 92	137 93	1 75	125 91	1 57	112 62	1 36	97 53	1 11	79 64	785	56 31	67 96
18	75 25	2 697	2 24	166 54	2 09	157 64	1 94	145 95	1 77	133 24	1 58	119 17	1 37	103 21	1 12	84 27	792	59·59	68 19
19	78 75	2 725	2 26	177 83	2 12	166 34	1 96	154·00	1 79	140·58	1 60	125 74	1 38	108 90	1 13	88 91	798	62 87	68 40
20	82 25	2 751	2 28	187 15	2 13	175 05	1 97	162 07	1 80	147 95	1 61	132 33	1 39	114 60	1 14	93 57	804	66 17	68 59

RAJBAHA VELOCITIES AND DISCHARGES—SIDE SLOPES 1 TO 1

Bed Width.	Area of water section	Mean Hydraulic depth	Fall of Channel in 5,000 feet																Co-efficient C
			2·00		1·75		1·50		1·25		1·00		0·75		0·50		0·25		
			V	D	V	D	V	D	V	D	V	D	V	D	V	D	V	D	
Depth of water, 4 feet																			
3	28·00	1·956	1·72	48·19	1·61	45·07	1·49	41·73	1·36	38·09	1·22	34·07	1·05	29·51	·860	24·09	·608	17·04	61·52
4	32·00	2·090	1·82	58·19	1·70	54·43	1·57	50·39	1·44	46·00	1·29	41·15	1·11	35·63	·909	29·09	·643	20·57	62·89
5	36·00	2·207	1·90	68·49	1·78	64·06	1·65	59·31	1·50	54·14	1·35	48·43	1·16	41·94	·951	34·24	·673	24·21	64·03
6	40·00	2·311	1·98	79·02	1·85	73·91	1·71	68·43	1·56	62·47	1·40	55·88	1·21	48·39	·988	39·51	·698	27·94	64·98
7	44·00	2·403	2·04	89·75	1·91	83·95	1·77	77·73	1·61	70·95	1·44	63·46	1·25	54·96	1·02	44·88	·721	31·73	65·80
8	48·00	2·486	2·10	100·64	1·96	94·14	1·82	87·16	1·66	79·56	1·48	71·17	1·28	61·63	1·05	50·32	·741	35·58	66·50
9	52·00	2·560	2·15	111·67	2·01	104·45	1·86	96·71	1·70	88·28	1·52	78·97	1·32	68·38	1·07	55·84	·759	39·48	67·11
10	56·00	2·628	2·19	122·81	2·05	114·88	1·90	106·36	1·73	97·09	1·55	86·84	1·34	75·21	1·10	61·41	·775	43·42	67·65
11	60·00	2·689	2·23	134·05	2·09	125·39	1·93	116·09	1·77	105·98	1·58	94·79	1·37	82·10	1·12	67·03	·790	47·40	68·12
12	64·00	2·745	2·27	145·38	2·12	135·99	1·97	125·90	1·80	114·93	1·61	102·80	1·39	89·03	1·14	72·69	·803	51·40	68·55
13	68·00	2·797	2·31	156·78	2·16	146·65	2·00	135·77	1·82	123·94	1·63	110·86	1·41	96·01	1·15	78·39	·815	55·43	68·93
14	72·00	2·845	2·34	168·24	2·19	157·37	2·02	145·70	1·85	133·01	1·65	118·97	1·43	103·02	1·17	84·12	·826	59·48	69·28
15	76·00	2·888	2·37	179·77	2·21	168·15	2·05	155·68	1·87	142·12	1·67	127·12	1·45	110·08	1·18	89·88	·836	63·56	69·59
16	80·00	2·929	2·39	191·34	2·24	178·97	2·07	165·70	1·89	151·26	1·69	135·30	1·46	117·17	1·20	95·67	·846	67·66	69·87
17	84·00	2·967	2·42	202·95	2·26	189·84	2·09	175·76	1·91	160·45	1·71	143·51	1·48	124·28	1·21	101·48	·854	71·76	70·14
18	88·00	3·002	2·44	214·61	2·28	200·74	2·11	185·86	1·93	169·66	1·72	151·76	1·49	131·42	1·22	107·31	·862	75·88	70·38
19	92·00	3·035	2·46	226·30	2·30	211·68	2·13	195·98	1·94	178·90	1·74	160·02	1·51	138·58	1·23	113·15	·870	80·01	70·60
20	96·00	3·066	2·48	238·03	2·32	222·64	2·15	206·13	1·96	188·17	1·75	168·31	1·52	145·76	1·24	119·01	·877	84·16	70·80

RAJBAHA VELOCITIES AND DISCHARGES—SIDE SLOPES 1 TO 1

Bed Width	Area of water section.	Mean Hydraulic depth.	Fall of Channel in 5,000 feet																Co efficient C
			2 00		1 75		1 50		1 25		1 00		0 75		0 50		0 25		
			V	D	V	D	V	D	V	D	V	D	V	D	V	D	V	D	
Depth of water, 4 5 feet																			
3	33 75	2 146	1 86	62 74	1 74	58 69	1 61	54 33	1 47	49 60	1 31	44 36	1 14	38 42	929	31 37	657	22 18	63 45
4	38 25	2 287	1 96	74 93	1 83	70 09	1 70	64 89	1 55	59 23	1 ,9	52 98	1 20	45 88	979	37 46	693	26 49	64 77
5	42 75	2 412	2 05	87 46	1 91	81 81	1 77	75 74	1 62	69 15	1 45	61 80	1 25	53 56	1 02	43 73	723	30 92	65 87
6	47 25	2 523	2 12	100 29	1 99	93 81	1 84	86 85	1 68	79 28	1 50	70 91	1 30	61 38	1 06	50 14	750	35 46	66 81
7	51 75	2 623	2 19	113 35	2 05	106 02	1 90	98 16	1 73	89 61	1 55	80 15	1 34	69 41	1 10	56 67	774	40 08	67 61
8	56 25	2 714	2 25	126 61	2 11	118 42	1 95	10,9 64	1 78	100 09	1 59	89 52	1 38	77 53	1 13	63 30	796	44 76	68 31
9	60 75	2 796	2 31	140 03	2 16	130 98	2 00	121 27	1 82	110 70	1 63	99 02	1 41	85 75	1 15	70 02	815	49 51	68 92
10	65 25	2 871	2 35	153 61	2 20	143 68	2 04	133 02	1 86	121 43	1 66	108 62	1 44	94 06	1 18	76 80	833	54 31	69 47
11	69 75	2 940	2 40	167 31	2 24	156 49	2 08	144 89	1 90	132 26	1 70	118 30	1 47	102 45	1 20	83 65	848	59 15	69 95
12	74 25	3 003	2 44	181 11	2 28	169 41	2 11	156 84	1 93	143 18	1 72	128 06	1 49	110 90	1 22	90 55	862	64 03	70 38
13	78 75	3 061	2 48	195 02	2 32	182 41	2 14	168 88	1 96	154 17	1 75	137 90	1 52	119 42	1 24	97 51	876	68 95	70 77
14	83 25	3 115	2 51	209 00	2 35	195 49	2 17	180 99	1 98	165 22	1 78	147 78	1 54	127 98	1 26	104 50	888	73 89	71 12
15	87 75	3 165	2 54	223 06	2 38	208 64	2 20	193 17	2 01	176 34	1 80	157 72	1 56	136 59	1 27	111 52	899	78 86	71 44
16	92 25	3 211	2 57	237 19	2 40	221 80	2 23	205 40	2 03	187 51	1 82	167 72	1 57	145 24	1 29	118 59	909	83 86	71 74
17	96 75	3 255	2 60	251 37	2 43	235 12	2 25	21[illegible]	2 05	198 72	1 84	177 75	1 59	153 93	1 30	125 68	919	88 87	72 01
18	101 25	3 296	2 62	265 61	2 45	248 44	2 27	230 02	2 07	209 98	1 85	187 81	1 61	162 65	1 31	132 80	927	93 91	72 26
19	105 75	3 333	2 65	279 89	2 48	261 80	2 29	242 38	2 09	221 26	1 87	197 91	1 62	171 39	1 32	139 94	936	98 96	72 48
20	110·25	3 369	2 67	294 21	2 49	275 20	2 31	254 80	2 11	232 59	1 89	208 04	1 63	180 17	1 33	147 11	944	104 02	72 70

RAJBAHA VELOCITIES AND DISCHARGES—SIDE SLOPES 1 TO 1

Bed Width	Area of water section	Mean Hydraulic depth	Fall of Channel in 5,000 feet																Co efficient C
			2.00		1.75		1.50		1.25		1.00		0.75		0.50		0.25		
			V	D	V	D	V	D	V	D	V	D	V	D	V	D	V	D	
Depth of water, 5 feet																			
3	40.00	2.333	1.99	79.64	1.86	74.52	1.72	68.96	1.57	62.96	1.41	56.32	1.22	48.76	.996	39.82	.704	28.16	65.19
4	45.00	2.480	2.09	94.20	1.96	88.11	1.81	81.58	1.66	74.47	1.48	66.61	1.28	57.69	1.05	47.10	.740	33.31	66.45
5	50.00	2.612	2.18	109.14	2.04	102.09	1.89	94.52	1.73	86.28	1.54	77.18	1.34	66.83	1.09	54.57	.772	38.59	67.53
6	55.00	2.731	2.26	124.40	2.12	116.36	1.96	107.73	1.79	98.35	1.60	87.97	1.39	76.18	1.13	62.20	.800	43.98	68.44
7	60.00	2.838	2.33	139.96	2.18	130.91	2.02	121.20	1.84	110.64	1.65	98.96	1.43	85.70	1.17	69.98	.825	49.48	69.21
8	65.00	2.936	2.40	155.74	2.24	145.68	2.08	134.88	1.89	123.12	1.69	110.13	1.47	95.37	1.20	77.87	.847	55.06	69.92
9	70.00	3.025	2.45	171.74	2.30	160.64	2.13	148.72	1.94	135.77	1.74	121.44	1.50	105.16	1.23	85.87	.868	60.72	70.53
10	75.00	3.107	2.51	187.91	2.34	175.76	2.17	162.73	1.98	148.55	1.77	132.87	1.53	115.07	1.25	93.95	.886	66.44	71.07
11	80.00	3.182	2.55	204.22	2.39	191.02	2.21	186.85	2.02	161.44	1.81	144.41	1.56	125.06	1.28	102.10	.903	72.20	71.55
12	85.00	3.252	2.60	220.68	2.43	206.41	2.25	191.11	2.05	174.45	1.84	156.04	1.59	135.13	1.30	110.34	.918	78.02	71.99
13	90.00	3.316	2.64	237.25	2.47	221.91	2.28	205.46	2.08	187.56	1.86	167.77	1.61	145.28	1.32	118.63	.932	83.88	72.38
14	95.00	3.376	2.67	253.93	2.50	237.51	2.32	219.90	2.11	200.74	1.89	179.55	1.64	155.49	1.34	126.96	.945	89.78	72.74
15	100.00	3.432	2.71	270.70	2.53	253.20	2.34	234.42	2.14	214.00	1.91	191.41	1.66	165.76	1.35	135.35	.957	95.71	73.06
16	105.00	3.484	2.74	287.55	2.56	268.97	2.37	249.02	2.17	227.33	1.94	203.33	1.68	176.09	1.37	143.78	.968	101.67	73.37
17	110.00	3.532	2.77	304.49	2.59	284.80	2.40	263.68	2.19	240.71	1.96	215.30	1.70	186.46	1.38	152.24	.979	107.65	73.64
18	115.00	3.578	2.80	321.47	2.61	300.70	2.42	278.40	2.21	254.14	1.98	227.32	1.71	196.87	1.40	160.74	.988	113.66	73.89
19	120.00	3.621	2.82	338.53	2.64	316.66	2.44	293.17	2.23	267.62	1.99	239.38	1.73	207.30	1.41	169.26	.997	119.69	74.13
20	125.00	3.661	2.85	355.64	2.66	332.65	2.46	307.98	2.25	281.15	2.01	251.48	1.74	217.78	1.42	177.81	1.01	125.73	74.35

No CXCI

TIMBERING OF PENT ROOFS

[*Vide* Plate XXII]

By Major W H Mackesy, F G S, *Assoc Inst* C E, *Asst Secretary, P W D, Punjab*

This Article is written in continuation of No. LVII, Professional Papers, Second Series, on the "Timbering of Flat Roofs," and deals chiefly with the most economical arrangement of Rafters, Purlins and Trusses for Pent Roofs—convenient rules for obtaining the scantling of common rafters and purlins are also given, as well as for the scantling of under-trussed girders for flat roofs. A table of breaking weights for square deodar pillars is appended This table was computed by Lalla Goorsahai, the head of the estimate department and drawing office of the P W Secretariat, Lahore, to whom the writer begs to express his obligations A note is added, giving an exact expression for the most economical spacing of the beams of a flat roof The notation generally is that employed in Thomason College Manual No IIIA (Applied Mechanics)

w = uniformly distributed permanent load per running foot of beam, &c

w' = normal wind pressure per running foot of beam, &c

$W = wL$

$W' = w'L.$

2 The general results of the investigations are as follows —

It is shown in paras 9—11, that the scantling of a common rafter may be computed by the strength formula as that of a horizontal beam of the same bearing loaded uniformly with $w + w_1$

3 It is shown in paras 12—15, that the scantling of a purlin, or horizontal rafter, may be computed by the strength formula, as that of a hori-

zontal beam of the same bearing, with vertical sides loaded uniformly with $nw + w_1$, also that in ordinary cases n may be taken $= 1·5$

A general formula (Eq 2c) is given, from which the value of n can be found under all circumstances

4 The general problem of the most economical arrangement of the timbers of a pent roof is investigated in paras 16—23, but it is to be understood that in all cases whether in flat or pent roofs, economy of construction must give place to structural requirements

5 It is shown in paras 20—22, that it is a wasteful arrangement to carry the common rafters of a pent roof directly on the trusses, and some practical suggestions are offered in paras 23—28, regarding the best arrangement of purlins and the type of truss to be selected in any particular case, as well as the best arrangement of joint at foot of principal rafter

6 Expressions are given in paras 28—41, for the scantlings of the principal rafters of trusses carrying common rafters directly, and for the scantlings of under-trussed beams carrying a flat roof, the principals and beams in such cases are under a double stress, from the longitudinal thrust and from the transverse load Failing an expression for the deflection of a beam under the double stress, no exact solution of the problem is possible, the following has therefore been taken as the best approximation at present attainable

Fig 1

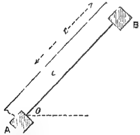
7 If AB be a rectangular beam subjected to a thrust in the direction of its length, the proper scantling can be determined from the rules in the text-books Let it be assumed that AB has such a scantling, if now a weight W is placed on the beam, the originally straight axis is deflected more or less, the thrust T causes a still further deflection, and the frame of which AB forms part, is rendered liable to failure If now we increase the scantling of AB, so that it may have an excess of strength and stiffness under T, we may safely apply a load W, provided that no part of the beam is thereby exposed to a greater stress than before There must always be *some* deflection caused by W, but if this condition be fulfilled, it seems probable that it will not be injurious

8 The method followed is to determine provisionally the uniform stress on the fibres of a pillar of sufficient scantling for the thrust, and then to increase the scantling so found, until the maximum stress on the extreme fibres of the new beam from the transverse load, + the uniform stress from the thrust, do not exceed the uniform stress on the fibres of the provisional pillar—when, however the pillar is smaller than a beam stiff enough for the transverse load alone, the scantling of the latter is increased, until the maximum stress on the extreme fibres of the new beam + the uniform stress from the thrust, does not exceed the maximum stress on the fibres of the provisional beam In no case should the combined stresses exceed f_c — 10

COMMON RAFTERS

9 If the rafter is free to slide at B, (i e , not securely spiked) a safe assumption to make the whole of the thrust along the rafter is taken by A, and when under a uniformly distributed vertical load w—this thrust increases uniformly from B to A—and at any point c distant a from B, $= xw \sin\theta$, and the uniform stress on the fibres at c

Fig 2



$$= \mathrm{p} = \frac{a\ w\ \sin\theta}{d\ b}$$

Also the bending moment from the part of the load resolved at right angles to the rafter at $c = \mathrm{M} = \frac{x\,(l - x)\,w\cos\theta}{2}$

the moment of resistance of the rafter at any point $c = \frac{bd^2 \times f}{6}$

$$f = \frac{3\,x\,(l - x)\,w\cos\theta}{b\ d^2},$$

f being the maximum stress on the extreme fibres Now to make $f + p$ a maximum, we have

$$\frac{x\ w\ \sin\theta}{d\ b} + \frac{3x\,(l - x)\,w\cos\theta}{bd^2} = u.$$

$$\frac{x\ w\ \sin\theta}{d\ b} + \frac{3\,xlw\cos\theta}{bd^2} - \frac{3\,x^2w\cos\theta}{bd^2} = u$$

$$\sin\theta + \frac{3\,l\cos\theta}{d} - \frac{6x\cos\theta}{d} = \frac{du}{dx} = 0$$

$$\therefore\ x = \tan\theta \cdot \frac{d}{6} + \frac{l}{2}$$

In ordinary cases, $\tan\theta \frac{d}{6}$ will be less than one inch, and as part of the longitudinal thrust will always be taken at B, it may be safely assumed that the maximum stress in the extreme fibres occurs at the centre of the rafter

10 Take a very extreme case—a deodar rafter 10 feet long—pitch 60°, $w = 50$, $w_1 = 40$, thrust $= 50 \sin 60^\circ = 43$ lbs., transverse load $= 50, \cos 60^\circ = 25$ lbs

Then for the transverse load alone—

$$bd^2 = \frac{65 \times 10 \times 10}{100} = 3\tfrac{1}{4} \times 4\tfrac{1}{2}^2,$$

The thrust in the case of a common rafter is always very small, and it will therefore suffice to add to the width on account of it * The requisite addition is $\frac{10}{2} \times 43 \times \frac{1}{600 \times 15} = 0\ 102$ inches, an insignificant increase, we may, therefore, always neglect the thrust—and the exact formula for a common rafter is (making the sides in the ratio of 2 3)

$$b = \sqrt[3]{\frac{20\ (w \cos\theta + w_1)\ s^2}{9 \times p}} \qquad (1)\dagger$$

For roofs of moderate pitch and loads of ordinary occurrence, $w + w_1$ will exceed $w \cos\theta + w_1 w$ but slightly In the above example, if the pitch were 30°, $bd^2 = \frac{83 + 100}{100} = 83$, or neglecting $\cos\theta$, $= \frac{90 + 100}{100} = 90$, representing respectively scantlings of $2'\tfrac{3}{4} \times 5'\tfrac{1}{2}$ and $3' \times 5'\tfrac{1}{2}$

We may, therefore, in ordinary cases make

$$b = \sqrt[3]{\frac{20\ (w + w_1)\ s^2}{9\ p}} \qquad (1a)$$

11 This rule gives ample stiffness under the *permanent* load For, take an extreme case—a deodar rafter, $w = 25$, $w_1 = 40$, $L = 10$—the coefficient of safety required to give sufficient stiffness under the *permanent* load is $\frac{3\ 62 \times 1\ 78}{2\ 236 \times 1\ 109} = 26$,‡ and the actual factor of safety is $\frac{65 \times 10}{25} = 26$

It seems wasteful to use the deflection formula for the whole load

* See Professional Papers on Indian Engineering [Second Series,] No CXXI , Eq 9

† As in the former Article, s = distance apart of the purlins from centre to centre

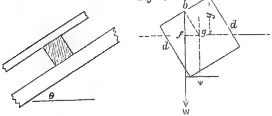
‡ See Professional Papers on Indian Engineering, [Second Series,] No LVII , Eq 14

$w + w_1$, as it is only during dust storms in India, lasting but a short time, that the wind is at all violent A five feet rafter $2'' \times 3''$ with this load (65 lbs) would only deflect 0 188 inches at the centre under the most violent wind—it is shown hereafter that common rafters should never be longer than about five feet It is thus only when long rafters are used, that their scantlings need be determined by the deflection formula, and in such cases, a deflection greater than $\frac{1}{40}$-inch per foot of span, seems to be fairly admissible

Purlins

12 Let W be the permanent vertical load (omitting wind pressure) acting on a purlin, at one side of the centre of gravity g This force is equivalent to a force W acting through g, and

Fig 3



to a couple whose moment $= \mathrm{W} \quad fg = \mathrm{W} \times \frac{d}{2} \times \sin\theta$ *

The effect of W through g will first be considered

The moment of resistance of a rectangular beam $= \frac{f\mathrm{I}}{y} = \mathrm{M}$, also θ being $=$ the slope of the rafter, we have†

$$\mathrm{I} = \frac{d^3 b \cos^2\theta + b^3 d \sin^2\theta}{12}$$

$$y = \frac{d\cos\theta + b\sin\theta}{2}$$ = the distance of the furthest point from the neutral axis

$$\mathrm{M} = \frac{f}{6} \quad bd\left(\frac{d^2\cos^2\theta + b^2\sin^2\theta}{d\cos\theta + b\sin\theta}\right)$$

If we put

$d = rb$, we have

$$\mathrm{M} = \frac{f}{6} \quad \frac{r^3 b^3 \cos\theta + r b^3 \sin^2\theta}{r\cos\theta + \sin\theta} = \frac{fb^3}{6} \quad k,$$

for sections of *equal strength*, putting $bd^2 = \mathrm{A} = r^2 b^3$

* Rankine, W M , Art 42

† Rankine, W M , Art 95, Eq 9

$M = \frac{fA}{6} \cdot \frac{r\cos^2\theta + \frac{1}{r}\sin^2\theta}{r\cos\theta + \sin\theta}$, equating the first different coefficient to zero, we have $r = \tan\theta\,(1 \pm \sqrt{2})$ makes M a minimum—for a pitch of 30°, $r = 1.39$ (This result serves to show that the maximum, r infinitely great, is unattainable) A greater value of r than 3 2 is not to be recommended

The following short table of the values of k is useful for purposes of comparison

$$\left(k = \frac{r\,(r^2\cos^2\theta + \sin^2\theta)}{r\cos\theta + \sin\theta} \right)$$

$d - b = r$	Values of θ			
	30°	35°	45°	60°
2	2 285	2 723	1 592	1 876
1 5	1 616	1 512	1 378	1 212
1	0 732	0 718	0 707	0 732

13. Let us now consider the effect of the moment of torsion, this for an equally distributed load $= \frac{1}{2}W \times \frac{1}{2}d\sin\theta$ over the principal and vanishes at the centre of the purlin, and unless the latter is treated as a continuous beam, may be neglected

Call the length of the purlin, l,

" its depth, d,

" the equally distributed permanent load, W,

we have (*see* Rankine's Civil Engineering, Eq 2, Art 174),

$T = \frac{W}{2} \times \frac{d}{2} \times \sin\theta = \frac{Wd\sin\theta}{4}$ The value of M will depend on the number of points of support over which the purlin is continuous—then

$$M_1 = \tfrac{1}{2}\left\{M + \sqrt{M^2 + T^2}\right\} = \frac{M}{2}\left\{1 + \sqrt{1 + (T \div M)^2}\right\}$$
$$= M_c$$

The complete equation is

$$M_c = \frac{b^3\,k}{6}\,\frac{f}{s} = \frac{3b^3kp}{s}, \qquad (2),$$

whence neglecting c, and putting $M = Wl \div 8$

$$b^3 = \frac{Wl\,s}{24\,pk}, \qquad (2a),$$

for factor of safety $= 10$, $\theta = 30^\circ$, $r = 1.5$, $12L = l$, this becomes

$$b^3 = \frac{3.09\,wL^2}{p}, \qquad (2b)$$

If the sides of the beam were vertical, the ordinary formula would apply,

$$\frac{Wl}{8} = \frac{bd^2\ f}{6 \times 10}$$

whence

$$b^3 = \frac{5wL^2}{r^2p},$$

hence Eq (2a) may be written (putting s as before $= 10$),

$$b^3 = \frac{5nwL^2}{r^2p}, \text{ where } n = \frac{r^2}{k} \qquad (2c),$$

for $\theta = 30^\circ$, $r = 1.5$, $n = 1.39$,

$\theta = 35^\circ$, $r = 1.5$, $n = 1.46$,

$\theta = 45^\circ$, $r = 1.5$, $n = 1.63$,

we may then take $n = 1.5$ for ordinary cases, leaving higher pitches than 35° out of consideration

Since the wind pressure w_1 always acts at right angles to the roof, for w_1, $\theta = 0$, and $k = r^2$, we have from Eq (2c) for purlins

$$b = \sqrt[3]{\frac{5\,(nw + w_1)\,L^2}{r^2p}}, \quad d = rb, \qquad (3)$$

For pitches up to 35°, $r = 1.5$, this becomes

The scantling so found gives ample *stiffness* under the permanent load

$$b = \sqrt[3]{\frac{20\,(1.5\,w + w_1)\,L^2}{9\,p}} \qquad (3a).$$

14 For example, take a deodar purlin 12 feet long under permanent load 40 lbs, wind pressure 40 lbs, if $s = 4$, $1\frac{1}{2}\,w + w_1 = 400$ lbs The factor of safety* required to give sufficient stiffness under the permanent load 240 lbs., is $\dfrac{1.861 \times 31.6}{3.933 \times 1.109} = 13.5$, the actual factor of safety for the permanent load is $\dfrac{100 \times 10}{60} = 16.6$, we have taken an extreme case, a very long purlin with a heavy *permanent* load, it is obvious that in *ordinary* cases the question of stiffness need not be considered.

15 No reduction of scantling is admissible on account of the additional strength given by the partial continuity of purlins or rafters over one or more trusses The condition cannot be certainly secured for *every* purlin and rafter, either in first construction or in subsequent repairs, and

* Professional Papers on Indian Engineering, [Second Series,] No LVII, Eq 14

further, purlins and rafters should always be notched down on the supporting principal or purlin

16 To determine the spacing which gives the least possible quantity of timber in Purlins and Rafters

Call as before spacing of purlins = length of rafter, s,

„ length of purlins, L,

„ load per running foot of rafter, $w + w_1$,

„ cost of Purlins per cubic foot, V,

„ „ Rafters „ v,

„ $d - b$, for Purlins and Rafters, respectively, R and r,

we have for *any* beam from the strength formula,

$$b^3 = \frac{5WL^2}{r^2 p},$$

W being the load per running foot

The area of section in square inches $= a = r b^2 = \left(\frac{5W}{p}\right)^{\frac{2}{3}} \cdot \left(\frac{L^4}{r}\right)^{\frac{1}{3}}$

and the cost $= \frac{Va}{144} \quad L = \frac{V}{144} \cdot \left(\frac{5W}{p}\right)^{\frac{2}{3}} \quad \frac{L^{\frac{7}{3}}}{r} \ \frac{1}{3} \left(r^{\frac{1}{3}}\right)$

putting $c = \frac{5^{\frac{2}{3}}}{p^{\frac{2}{3}} \times 144}$, the cost $= CVW^{\frac{2}{3}} \ L^{\frac{7}{3}} \ r^{-\frac{1}{3}}$

$$\left.\begin{array}{l} \text{For deodar } c = \frac{1}{3102} \\ \text{„ } r = 1.5, \ \sqrt[3]{r} = 1.1447 \end{array}\right\} c r^{-\frac{1}{3}} = \frac{1}{3551}$$

Then we have the cost per running foot (measured along the slant) of one bay

Rafters, $\frac{L}{s} \quad c v r^{-\frac{1}{3}} \ (w + w_1)^{\frac{2}{3}} \ s^{\frac{7}{3}}$

$$= Lcvr^{-\frac{1}{3}} \ (w + w_1)^{\frac{2}{3}} \ s^{\frac{4}{3}} = As^{\frac{4}{3}}$$

Purlin, $\frac{1}{s} \quad cVR^{-\frac{1}{3}} \left\{ (nw + w_1) s \right\}^{\frac{2}{3}} L^{\frac{7}{3}}$

$$= L^{\frac{7}{3}} \ cVR^{-\frac{1}{3}} (nw + w_1)^{\frac{2}{3}} \ s^{-\frac{1}{3}} = Bs^{-\frac{1}{3}}$$

Equating first diff coefficient of $As^{\frac{4}{3}} + Bs^{-\frac{1}{3}} = u$ to zero, we have

$$s = \left(\frac{B}{4A}\right)^{\frac{3}{5}} = \left(\frac{1}{4}\right)^{\frac{3}{5}} \times \left(\frac{V}{v}\right)^{\frac{3}{5}} \times \left(\frac{r}{R}\right)^{\frac{1}{5}} \times \left(\frac{nw + w_1}{w + w_1}\right)^{\frac{2}{5}} \times L^{\frac{4}{5}}, \quad . (4)$$

Now in ordinary cases $V = v$, and $R = r$, also $\left(\frac{1}{4}\right)^{\frac{3}{5}} = 0.43528 = \frac{1}{2.297}$

for $w = 10$, $w_1 = 10$, $L = 5$, $n = 1.5$, $s = 1{\cdot}639$,

for $w = 40$, $w_1 = 40$, $L = 12$, $n = 1.5$, $s = 2.789$,

These are extreme cases—we cannot practically use so small a scantling of

common rafter as 1″ 36 × 2″ 04,* the smallest section admissible for deodar is 2″ × 3″, and if the purlins are placed closer together than the spacing which this section of rafter can safely span, there is of course waste Assuming a section 2″ × 3″ for the common rafters, the most economical spacing of purlins is as below

$$\left.\begin{array}{lllll} w + w_1 = \text{lbs}, & 50 & 60 & 70 & 80 \\ s = \text{feet}, & 6 & 5\ 48 & 5\ 07 & 4\ 74 \end{array}\right\} \text{for deodar}$$

About five feet is thus the most economical spacing for deodar purlins for *ordinary* roofs

17 To compare the cost (leaving the trusses out of consideration) of rafters and purlins and of rafters laid purlinwise, (horizontal rafters,) we have

Cost of one horizontal rafter (calculated as a purlin)—

$$= cv\,(nw + w_1)^{\frac{2}{3}}\; r^{-\frac{1}{3}}\; \mathrm{L}^{\frac{7}{3}} = a,$$

Cost of a bay of rafters for one running foot—

$$= \mathrm{L}cv\,(w + w_1)^{\frac{2}{3}}\; r^{-\frac{1}{3}}\; s^{\frac{1}{3}} = b,$$

Cost of purlin for one running foot—

$$= s^{-1}\; c\mathrm{V}\,(nw + w_1)^{\frac{2}{3}}\, s^{\frac{2}{3}}\, \mathrm{R}^{-\frac{1}{3}}\, \mathrm{L}^{\frac{7}{3}} = c,$$

then putting $a = b + c$, we have the spacing of trusses at which the cost is equal

$$= \mathrm{L} = \left(\frac{w + w_1}{nw + w_1}\right)^{\frac{1}{4}} \frac{r^{\frac{3}{4}}\, s^{\frac{5}{4}}\, \mathrm{R}^{\frac{1}{4}}}{\left(v s^{\frac{1}{3}} \mathrm{R}^{\frac{1}{3}} - \mathrm{V} r^{\frac{1}{3}}\right)^{\frac{3}{4}}} \quad \ldots\ldots \quad (5)$$

If we put $v = \mathrm{V}$, and $r = \mathrm{R}$, this becomes

$$\mathrm{L} = \left(\frac{w + w_1}{nw + w_1}\right)^{\frac{1}{4}} \frac{s^{\frac{5}{4}}}{\left(s^{\frac{1}{3}} - 1\right)^{\frac{3}{4}}} \quad \ldots\ldots \quad (5a)$$

If we take	$w_1 =$	40	40	40	40 lbs,
	$w =$	10	20	30	40 lbs,
then	$\sqrt{\frac{w + w_1}{1\ 5\, w + w_1}} =$	9535	9258	9070	8914,
and if we take	$s =$	6	5 5	5 0	4 75 feet,
then	$\frac{s^{\frac{5}{4}}}{\left(s^{\frac{1}{3}} - 1\right)^{\frac{3}{4}}} =$	10 927	10 295	9 667	9 351 feet

* $\sqrt[3]{\frac{2\ 2 \times 80 \times \overline{2\ 79}^2}{600}} = 1\ 36$

From the above factors

taking $s = 6$, $w = 10$, $w_1 = 40$,

we have $L = 10\ 927 \times 9535 = 10\ 4$ feet,

and taking $s = 4\ 75$, $w = 40$, $w_1 = 40$,

we have $L = 9\ 354 \times 8944 = 8\ 35$ feet, thus *so far as cost of the timber in purlins and rafters is concerned*, it is more economical to use horizontal rafters for truss spacings less than L as found from Eq 5

18 We will now proceed to investigate the question of the most economical arrangement of roof timbering, taking trusses, purlins and rafters into consideration

Each principal rafter of a timber truss is under a thrust in the direction of its length, and its scantling must, as already explained, be determined as that of a pillar under the same vertical load Let AD, *Fig* 4 or 5, be a principal loaded at B and C by purlins, and strutted under each purlin. The thrusts on the sections 1, 2 and 3, are approximately as those numbers Now AD is rigidly fixed at B and C by the purlins above, struts below, and by the purlins laterally, if we suppose the thrust to be so great, that the section AB is just on the point of bending, the section BC on which the thrust is $\frac{2}{3}$ of that on AB, and still more the section CD, has a considerable excess of rigidity, it is also obvious that any flexure in AB causes a simultaneous flexure in BC and CD We see, therefore, that under such a load, the mean fibre at B is fixed in direction, while the mean fibre at A is free to bend The section AB must therefore be considered as a pillar fixed at B and free at A

19 Gordon's formula the coefficients used with which are based on Hodgkinson's extensive experiments, is the most trustworthy formula extant for determining the dimensions of pillars, it gives a larger scantling for timber pillars than Rondelet's formula, which is frequently used in India The discontinuity of the reciprocals of Rondelet's multipliers (which will be seen by taking the second differences) alone suffices, show that his formula is not correct

Timber post, both ends fixed

Ratio $l - d$	Rondelet s multipliers and their Reciprocals		Gordon s Divisors
12	$\frac{5}{6}$	1 2	1 57
24	$\frac{1}{2}$	2 0	3 30
36	$\frac{1}{3}$	3	6 2
48	$\frac{1}{6}$	6	10 2
60	$\frac{1}{12}$	12	15 4
72	$\frac{1}{24}$	24	21 7

Gordon's formula is $P = 10T = \dfrac{f_c A}{1 + C\dfrac{l^2}{d^2}}$

where A = area of section = d^2 for square pillars

and $C = \dfrac{16}{9 \times 250}$ for dry timber for pillars fixed at one end

$= \dfrac{1}{140\,625}$

whence for square pillars $\quad d^2 = \dfrac{5T}{f_c}\left\{1 \pm \sqrt{1 + \dfrac{0\,4\, f_c\, l^2\, C}{T}}\right\}$

A Table of the values of $10T = P$ for square deodar pillars is appended It can be made applicable to any kind of timber or area of section

Taking as examples extreme values of l and T, we have for deodar

$1 \pm \sqrt{1 + \dfrac{0\,4\, f_c\, l^2\, C}{T}}$ equivalent to 2 066 when (l=12, and T=18,000)
and to 2 018 ,, (l=4 5, ,, T= 9,500)

In cases of *ordinary* occurrence, we have therefore d^2, or the sectional area of the principals, approximately proportional to the thrust, which is directly proportional to the spacing for any given span and pitch, and similarly for the struts The areas of king post and tie-beam are directly proportional to the spacing Hence, we have the timber in a truss for any particular span and pitch, and consequently the cost of the truss approximately proportional to the bearing of the purlins

20 If therefore the same scantling would answer for the principals, whether the trusses were intended to carry purlins or horizontal rafters, it would be cheapest to use horizontal rafters of the smallest admissible scantling, spacing the trusses at the corresponding distance apart, [we find however, *see* paras 29 and 30, that a considerable increase of scantling is required for rafter trusses] These spacings are given in the following table for deodar for various values of w_1 and w, (calculated from the formula for purlins)

w	w_1		
=	=		
10	40	Maximum bearing of horizontal rafters of deodar, scantling 3″ × 2″	5 72 feet
20	40		5 07 ,,
30	40		4 60 ,,
40	40		4 24 ,,

We have then the following problem to solve—at what spacing of purlin trusses will the cost of timbering be the same as if rafter trusses

were used, the rafter trusses being spaced to suit the minimum section of rafters

21 The general solution of the Problem is as follows —

Put length of room to be roofed,	$= l$,
„ number of divisions in the purlin truss,	$= n'$,
„ „ bays in purlin trussed roof at which cost of trusses and purlins equals the cost of the rafter trusses,	$=$ N,
„ approximate cost of one purlin truss,	$=$ P,
„ for a provisional number of bays,	$= v$,
„ cost of the rafter trusses required for the room,	$=$ R

The spacing of the rafter trusses must be that which suits horizontal rafters of the same scantling as the common rafters of the purlin roof, so that in either case, the quantity and cost of the common rafters is the same

In order to obtain P and R, rough design and estimates must be made for trusses for the particular span to be roofed, and style of roof covering proposed.

We have

$$R = \frac{v}{N} P(N-1) + ln' \times \text{cost of one purlin}$$

The cost of a purlin truss per running foot of bay $= P \times \frac{v}{l}$, and cost of all the purlin trusses required $= (N-1) P \frac{v}{l} \frac{l}{N} = \frac{vP}{N}(N-1)$

(It is assumed that the two pole plates and the ridge pole are together equivalent in cost to two purlins)

Also the cost of one purlin $= \frac{V}{144} \left\{\frac{(6n's)^2}{rp^2}\right\}^{\frac{1}{3}} \frac{l^{\frac{7}{3}}}{N^{\frac{4}{3}}} = \frac{Al^{\frac{7}{3}}}{N^{\frac{4}{3}}}$

$$\therefore R = \frac{v}{N} P (N-1) + n' \cdot \frac{Al^{\frac{7}{3}}}{N^{\frac{4}{3}}}$$

$$\text{and } N^{\frac{4}{3}} + \frac{vP}{R-vP} \cdot N^{\frac{1}{3}} - \frac{n'Al^{\frac{7}{3}}}{R-vP} = 0, \quad \ldots\ldots (6)$$

Whence N can be obtained by approximation

Example.—A room 25 feet span and 48 feet long Pitch of roof 30°, $w = w_1 = 40$ lbs, $n' = 4$, V = Rs 1-8-0

For a spacing of 8 feet, a purlin king post truss of deodar timber at

Rs 2-8-0, would cost about Rs 60, the principals being $6\frac{1}{2}$ inches square

Whence $P = 60$, $v = \frac{48}{8} = 6$

For a spacing of 4 feet, a rafter truss, the principals measuring $8\frac{1}{4}'' \times 5\frac{1}{2}''$, would cost about Rs. 50, whence

$$R = 50 \times \left(\frac{48}{4} - 1\right) = \text{Rs } 550$$

Then

$$N^{\frac{4}{3}} + \frac{6 \times 60}{550 - 360} N^{\frac{1}{3}} - \frac{61 \times .04224 \times 8373.8}{190} = 0,$$

$$\text{and } N^{\frac{4}{3}} + 1.9\, N^{\frac{1}{3}} - 7.448 = 0,$$

$$\text{whence } \sqrt[3]{N} = 1.51145, \text{ and } N = 3.453$$

There may be four bays of 12 feet each in the length of the room. The scantling required of each purlin for bearing of 12 feet is $7''.7 \times 11''.5$

$$b = \sqrt[3]{\frac{20 \times 100 \times 7.1 \times 144}{9 \times 500}}$$

$$b = 7.688 \text{ inches},$$

$$d = 1.5b = 11.532 \text{ inches},$$

$$\text{spacing of purlins} = \frac{14.2}{2} = 7.1 \text{ feet}$$

We have then, cost of purlin trusses and purlins,—

Purlins,	$4 \times 48' \times \frac{7.7 \times 11.5}{144} \times 1.5$	= Rs 177
Trusses,	$\frac{6 \times 60 \times 3}{4}$	= „ 270
	Total,	„ 447

The cost of the rafter trusses being Rs 550, it follows that trusses and purlins would in this case cost the same as rafter trusses, at Rs 40-10 each, instead of Rs 50, as assumed

22 We see from this formula and example, that it can never be economical to carry the common rafters directly on the trusses If the rafter trusses are spaced further apart than indicated above, stronger rafters are required, the quantity of timber in the rafters increases as the cube root of the fourth power of their bearing For instance, the quantity of timber is doubled if the bearing is increased two-thirds (the exact proportion is 1 : 1.682).

23 It follows, therefore, generally, that the most economical arrangement is to space the trusses carrying purlins at a moderate distance apart, not too close, in order to reduce the cost of labor and of erection Probably 8 to 10 feet is the best distance, but the problem does not admit of an exact solution in the absence of an expression for the exact value of P in para 21, *see* also para 19

24 Two or more purlins are sometimes placed at either side of the struts of a king post truss, thus bringing a transverse load on the principal, this should never be done, unless the permanent load is very small There should be a strut under each purlin, and this is always practicable.

Fig 4

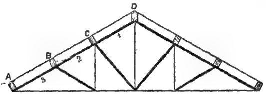
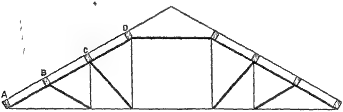


Fig 5.



25 It has been shown that the most economical spacing for purlins, is that which the smallest allowable section of common rafter will safely span—about 5 feet, say 4 to 6 feet in *ordinary* cases The ordinary king post type of truss can, therefore, be employed up to a length of principal of about 12 feet, equivalent (for a pitch of 30°) to a span of say 20 feet The type of truss, *Fig* 4, or the queen post type with one strut, should be employed for spans of from 20 feet to 30 feet, or for lengths of principal from 12 to 18 feet, and finally the type of truss, *Fig* 5, for spans of from 30 to 42 feet, or for lengths of principal from 18 to 24 feet Suitable designs for types 4 and 5, and for queen post trusses with one strut, will

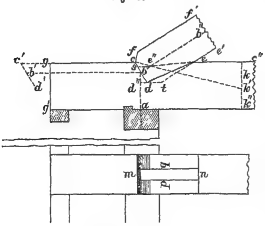
be found in the Roorkee Treatise, Vol I, 1873, *Plate* XXX, *Figs* 6, 7, and 8, and *Plate* XXIX, *Figs* 2 and 3.

The stresses for *Fig* 4 will be found in *Plate* LXVI, and for *Fig.* 5 in *Plate* LXVII., slightly modified when there are two struts.

26 Having decided on the spacing of the trusses and their type, determine the stresses in the various parts The scantling of the lower section of the rafter is calculated as that of a pillar fixed at one end and free at the other, and the scantling of the struts as pillars free at both ends. Or the scantlings of both rafter and struts can be obtained by inspection from the table of posts

27 The most important joint in the truss is that between rafter and tie-beam,—it is best designed as follows, *see Fig* 6.

Fig 6.



Scale, $\frac{1}{12}$th full size

The figure represents a joint at foot of a principal $6\frac{1}{2}'' \times 6\frac{1}{2}''$, thrust $= 16{,}863$ lbs., and tension on tie $= 14{,}900$ lbs $= 8{\cdot}7$ tons The area of joint $= \frac{16863}{1000} =$ 16·9 square inches,* and its depth $cd = \frac{3 \times 16{\cdot}9}{2 \times 6{\cdot}5} =$ 3·91 inches, say 4 inches Its position is thus found—bisect the wall plate by a vertical line ab, draw any line $c'd'$ at right angles to the direction of the pitch of the rafter, make it 4 inches long, bisect it in b', draw $c'cc''$ and $b'b$ at right angles to ab, and draw cbd parallel to $c'd'$ through b, and make $cd = c'd'$, then $c'cc''$ is the top of the tie-beam, and cd the joint Draw bb'' at right angles to cd for the axis of the principal, and draw ee' and ff' at equal distances

* The width (gp) of the bridle mn is $\frac{1}{3}$ the width of the tie, if the bridle is omitted, and a tenon die given on the principal, the whole surface is effective, and $cd = \frac{16{\cdot}9}{6{\cdot}5} = 2{\cdot}6$ inches, effecting a saving of timber in the tie—the first arrangement is preferable

at either side of bb'' and parallel thereto for the bottom and top of the principal Join ed (This construction makes the resultant of the reaction at the joint pass through the axis of the principal—a necessary condition to secure its full calculated strength) Draw $d''d$ at right angles to ba A notch (cse'' in elevation, ms' in plan) may be given in the bridle, sc may be from $\frac{1}{3}$ to $\frac{1}{4}$ cd

The area required for the tie is $\frac{14\,900}{700}$ square inches, and the width being $6\frac{1}{2}$ inches, the depth must be not less than $\frac{14900}{700 \times 6\,5} = 3\,25$ inches—$1\frac{1}{4}$ inches additional may be allowed for notching on wall plate and for contingencies, total 4 5, which is set off from d'' to a, making the total depth of tie 8 inches. Set off eg, dk each equal to $\frac{14900}{150 \times 6\,5} = 15\,3$, say 16" Draw gg' and $kk'k''$ at right angles to gcc', the tie is cut off at gg'

Set off $k''\ k' = \frac{1}{2}$ depth of tie $-$ 1 inch, and join ck', which gives the bottom line of the strap The tension on tie when resolved, gives a tension of 9 tons on the strap, or 4 5 tons on each side, allowing a thickness of $\frac{5}{8}''$ and 5 tons per square inch, the requisite width of strap is $\frac{4\,5 \times 8}{5 \times 5} = 1\,44$ inches, say $1\frac{1}{2}$ inches, ($1\frac{1}{2}'' \times \frac{5}{8}''$). Set off cf at right angles to ck' for the abutment of the strap The safe shear on a round bolt $1\frac{1}{8}''$ diameter is 5 tons, and the strap should be secured to the tie by a bolt of this diameter The centre of the bolt hole should be on the line $c'\ k''$

The horizontal component of the thrust along $b''b$ tends to bend down the end of the tie, and brings a cross strain on da In the form of joint shown in figure, the bridle in the tie (cde in elevation, mn in plan) helps to resist this action In heavy trusses, there should in addition be a small wall plate at the end of the tie-beam.

28 King post truss with uniformly distributed load, *see Fig* 7. If x = the distance of any point p from V, we have the thrust at $p = wx \sin\theta$ + the thrust resulting from the permanent load and wind pressure acting at right angles to the principals, + the thrust produced by the weight of tie, struts, king post and ridge acting at V Since AV is a continuous beam, bisected and supported at B, we have portion of W

$$\left.\begin{array}{lllll} \text{acting at right angles to rafter at} & & & \text{A}^* & = \frac{3}{16}\,wL\cos\theta, \\ \text{,,} & \text{,,} & \text{,,} & \text{,,}\ \ \text{B} & = \frac{10}{16}\,wL\cos\theta, \\ \text{,,} & \text{,,} & \text{,,} & \text{,,}\ \ \text{V} & = \frac{3}{16}\,wL\cos\theta, \end{array}\right\} \quad (11)$$

* Stoney, Eq 172–3

The exact expression for the total thrust at any point in AV is complicated, and is separately investigated in Note A at end of this Article

Considering AV as under a thrust alone, each section AB, BV, may be treated as a post fixed at one end and free at the other end In consequence of the lateral support given by the rafters and the action of the transverse load, deflection can only take place downwards, and the principal is solicited to assume a curve A″eeB″eeV, hence d in Gordon's formula is the depth of the principal

As a provisional scantling, we have from Gordon's second formula, putting AV = L, and making the breadth of the principal two-thirds of the depth

$$d_1^2 = \frac{7\ 5\ \mathrm{T}}{f_c}\left(1 \pm \sqrt{1 + \frac{f_c \mathrm{L}^2}{14\ 648\ \mathrm{T}}}\right) \qquad (7),$$

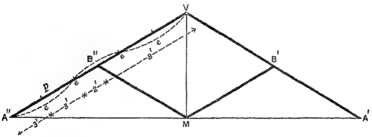
or for deodar, d_1 can be obtained directly from the table of square pillars fixed at one end and free at the other, by entering the table with P = 15T, and L = half length of principal

Then the uniform stress on the provisional pillar

$$= f = \frac{1\ 5\ \mathrm{T}}{d^2} = \frac{1}{5}\ \frac{f_c}{1 \pm \sqrt{1 + \frac{f_c \mathrm{L}^2}{14\ 648\ \mathrm{T}}}} \qquad (8)$$

29 Considering AV as under a transverse load only, it may be treat-

Fig 7



ed as a continuous girder of two equal spans loaded uniformly * The greatest bending moment is at B, and the maximum stress on the extreme fibres at this point $= f_{11} = \frac{2\ 25\ (n \cos\theta + w_1)\ \mathrm{L}^2}{b_1 d_1^2}$ also the maximum combined stresses at B must not exceed $f_1 + f_{11} = f$ Let bd be the scantling required, then $f_1 = \mathrm{T} - bd$, whence for the general equation we have

* Stoney's Theory of Strains, page 161

$$f = \frac{T}{bd} + \frac{2\ 25\ (w \cos\theta + w_1)\ L^2}{bd^2} \quad (9),$$

If d is assumed

$$b = \frac{T}{fd}\ \left(1 + \frac{2\ 25\ (w \cos\theta + w_1)\ L^2}{Td}\right), \quad (9a)$$

If b is assumed, we have

$$d = \frac{T}{2\ fb}\ \left(1 + \sqrt{1 + \frac{9\ fb\ (w \cos\theta + w_1)\ L^2}{T^2}}\right) \quad (9b)$$

If d is assumed $= rb$, we have

$$d^3 - \frac{rT}{f} \cdot d - \frac{2\ 25\ (w \cos\theta + w_1)\ rL^2}{f} = 0, \quad (9c),$$

or if we make the ratio of breadth to depth of the principal $= 2\ \ 3$, (probably the most suitable ratio,) we have

$$d^3 - \frac{1\ 5\ T}{f}\ \ d - \frac{3\ 375\ (w \cos\theta + w_1)\ L^2}{f} = 0, \quad (9d)$$

30 *Example*—A truss, pitch 35°, span 28 feet, spacing 5 feet, $w = w_1 = 40 \times 5 = 200$ lbs, $W = W_1 = 12\ 2 \times 200 = 2{,}440$, we have the thrust at B (*see* Note A) $= 4{,}900$ lbs, and thrust midway between A and B $= 4{,}900 - 350 = 4{,}550$ lbs $= 2\ 04$ tons Entering the table under 6 feet, column 2, with $\frac{2\ 04 \times 10 \times 3}{2} = 30\ 6$ tons, we have the requisite provisional depth $= 5\frac{1}{4}''$,

whence

$$f = \frac{4{,}550}{5\frac{1}{4} \times 3\frac{1}{2}} = \text{say } 256 \text{ lbs},$$

then

$$d^3 - \frac{1\ 5 \times 4900}{256}\ d - \frac{3\ 375\ (1998 + 2440)\ 12\ 2}{256} = 0,$$

$$d^3 - 28\ 71\ d - 713\ 8 = 0,$$

whence

$d = 10$ inches

$b = 6\frac{2}{3}$ "

Proof—

$$\frac{2{\cdot}25 \times 4430 \times 12\ 2}{6\frac{2}{3} \times 10 \times 10} = 187 \text{ lbs} = \left\{\begin{array}{l}\text{max stress on extreme fibres at} \\ \text{B from the transverse load}\end{array}\right.$$

$$\frac{4900}{10 \times 6\frac{2}{3}} \qquad = \frac{72}{259} = \begin{array}{l}\text{uniform stress from thrust} \\ \text{max stress on extreme fibres at any point in the beam}\end{array}$$

If the load were carried on a similar truss by purlins and ridge pole over the trussed points, the thrust on the lower section of the principal

$$\left.\begin{aligned}&= \left(\frac{3 \times 2440}{4} + 200\right) \operatorname{cosec} 35^{\circ *}\\ &+ \frac{2440}{4}(3 - \sec^2 35^{\circ}) \cot 35^{\circ}\end{aligned}\right\} = 3{,}539 + 1{,}322 = 4{,}861 \text{ lbs}, = 2\ 18 \text{ tons}$$

The length of the lower section of the rafter being 6 feet, the principal should be $4\frac{3}{4}''$ square (*see* table) or an area $(4\frac{3}{4})^2 = 22\ 5625$ sq inches against $10 \times 6\frac{1}{3} = 63\ 3$ square inches for the uniformly loaded truss, showing that the latter requires much more timber than the former The arrangement is not a good one on this account, and should be avoided, except possibly in the case of roofs of high pitch and moderate span with a light roof covering

31 Simple symmetrical truss—load uniformly distributed, *see Plate, Fig* 18. The greatest stress occurs close to the centre of the principal at the side of the wind First considering the principal as a pillar free at both ends, calculate d_1 or take it out from the table, then $f = T' - b_1 d_1$ (In this case, and generally if d_1 obtained from Gordon's formula, or from the table, is more than one-tenth the length of the pillar—put $f = f_c - 10$)

Again considering A'V as under a transverse load only (*see* Note B), it may be treated as a beam supported at the ends and uniformly loaded

The greatest stress on the extreme fibres is at the centre, and $f_{11} = \frac{9\ (w \cos \theta + w')\ L^2}{b_1\ d_1^2}$, then the general equation is

$$f = \frac{T}{bd} + \frac{9\ (w\ \cos\theta + w')\ L^2}{bd^2}, \qquad (10),$$

b and d being the required dimensions of the beam

If we assume $$db = \frac{T}{fd}\left(1 + \frac{9\ (w \cos\theta + w)\ L^2}{Td}\right) \qquad (10a)$$

If we assume $$bd = \frac{T}{2fb}\left(1 \pm \sqrt{1 + \frac{36\ fb\ (w \cos\theta + w')\ L^2}{T^2}}\right) \ (10b)$$

And if we assume $b = 2d - 3$, $d^3 - \frac{1\ 5\ T}{f} - \frac{13\ 5\ (w \cos\theta + w')\ L^2}{f} = 0$, (10c)

32 In the case of this truss, the provisional pillar will usually be considerably smaller than the provisional beam, when this is the case, f should be deduced from the scantling suited for the latter, which has to be first calculated, $f = \frac{9\ (w\ \cos\ \theta + w')\ L^2}{b_1\ d_1^2}$, or f can be calculated directly by combining this formula with that for the deflection of a uniformly loaded beam,

$$f = 0\ 89 \sqrt{\frac{(w \cos\theta + w')\ E^3}{L}}$$

* Thomason Civil Engineering College Manual No IIIA, pages 567 and 568

But if f so found exceeds $f_c - 10$, the latter value should be adopted.

33 *Example*.—Truss—pitch 35°, span 14 feet, spacing 5 feet, $w = w_1 = 40 \times 5 = 200$ lbs

$W = W' = 6.1 \times 200 = 1{,}220$ lbs

Thrust at centre of $A'V = 583$ lbs, the provisional beam is evidently greater than the pillar,

$$f = 0.89 \sqrt[4]{\frac{364 \times (2500)^3}{6}} = 877, \text{ this exceeds } 6{,}000 - 10 = 600,$$

we therefore take $f = 600$

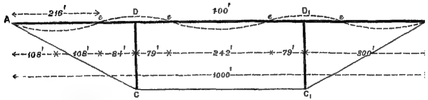
We have then,

$$d^3 - \frac{1.5 \times 583}{600}\, d - \frac{13.5 \times 364 \times 36}{600} = 0,$$

or $d^3 - 1.46\, d - 294.84 = 0$, whence $d = 6.8$, and the scantling may be $7'' \times 4\frac{1}{2}''$

34 Inverted Queen Post truss with struts DC and D_1C_1, *Fig.* 8 The beam when loaded is solicited to assume a curve $AeDeeD_1eB$

Fig 8



Considering AB as under a thrust alone AD, D_1B, are in the condition of posts fixed at one end (D) and free at the other, while the central portion D_1D is in the condition of a post fixed at both ends The thrust and section of the beam being uniform, putting $AD = BD_1 = l$, $DD = l_1$, we have from Gordon's second and third formulæ

$$\frac{f_c\, A}{1 + \frac{16}{9}\, c \left(\frac{l}{d}\right)^2} = \frac{f_c\, A}{1 + c\, \left(\frac{l_1}{d}\right)^2},$$

whence $l_1 = \frac{4}{3}\, l$, hence in order that the sections may be equally strong under the thrust, the following proportion must hold

$$AD\ (= BD_1) : DD_1 :: 3 : 4$$

Again considering AB as under an uniformly distributed transverse load alone, in order that the mean fibre at D and D_1 may be horizontal, we

ust have $AD = D_1B \quad DD_1$, $AD \quad DD_1 \quad 1 \quad 2\sqrt{3 \div 8} \quad 31 \quad 38$,
putting $\tan\beta = 0$, in Stoney, Eq 179)

The divisions of the beam may therefore be in the ratio of 3 4

35 The distribution of the load is found as follows —

Putting $AB = L$ and

R = reaction at wall plate

W = load at D_1D,

we have*

$$\therefore R = 0\ 1078\overline{703}\ wL \text{ and } W = 0\ 3921\overline{296}\ wL$$

also $2(R + W) = wL$ The positions of the points of inflexion are marked in *Fig* 5

Hence

$$T = \frac{0\ 3\ L + 1}{DC} \times 0\ 392\ wL, \qquad (11)$$

also tension on tie

$$= T\sqrt{1 + \left(\frac{DC^2}{0\ 3\ L + 1}\right)} \qquad (11a)$$

36 From Gordon's third formula, we have for the provisional scantling, putting $d = \frac{3b}{2}$, and remembering that the length of the central section $= 0\ 4\ L$

$$d_1^2 = \frac{7\ 5\ T}{f_c} \times \left(1 \pm \sqrt{1 + \frac{f_c L^2}{40\ 69\ T}}\right) \qquad (12),$$

or d may be found by inspection from the table, which should be entered with $P = 15T$, and $L = 0\ 4 \times$ span, then

$$f = \frac{3T}{2d_1^2} = \frac{1}{5}\ \frac{f_c}{1 \pm \sqrt{1 + \frac{f_c L^2}{40\ 69T}}} \qquad (13).$$

37 The maximum stress on the extreme fibres from the transverse load occurs at D_1D, its value is

$f_{11} = \frac{0\ 912924\ wL^2}{b_1 d_1^2}$, but the maximum combined stresses at D_1D must not exceed $f_1 + f_{11} = f$ We have, therefore, (b and d being the scantling required) $f_1 = T - bd$ The general equation is

$$f = \frac{T}{bd} + \frac{0\ 912924\ wL^2}{bd^2}, \qquad (14),$$

whence assuming any convenient value for d, we have

$$b = \frac{1}{df}\left(T + \frac{0\ 913\ wL^2}{d}\right), \qquad (14a)$$

If b is assumed, we have

$$d = \frac{T}{2bf}\left(1 \pm \sqrt{1 + \frac{3\ 65\ bwf\ L^2}{T^2}}\right) \qquad (14b)$$

If r is assumed, we have

$$d^3 - \frac{rT}{f}\,d - \frac{0\ 913\ wr\ L^2}{f} = 0, \qquad (14c)$$

* Stoney, Eqs 186 7 8 9

The maximum tension on the tie is given by Eq 11a In designing the tie, it should be remembered that the iron obtainable in the Indian market is is often bad in quality, and the actual load on flat roofs may equal, or even exceed, the intensity of 100 lbs per square foot usually assumed. This is more particularly the case with mud roofs, which are liable to increase in thickness from year to year by the addition of mud plaster or leeping In the case of pent roofs, where 5 tons per square inch is allowed for iron in tension, the permanent load falls far short of this limit, which is only reached during violent storms

38 *Example*—Queen-post truss of deodar timber 25 feet bearing, depth 30 inches, $w = 600$ lbs

Eq 11 $\mathrm{T} = \frac{8.5}{2.5} \times 0.392 \times 600 \times 25 = 19{,}898 \text{ lbs} = 8.9$ tons

Eq 11a Tension on tie $= 8.9\sqrt{1 + \left(\frac{2.5}{8.5}\right)^2} = 8.9 \times 1.188 =$ 10.1 tons

One tie of $1\frac{5}{8}''$ diameter would be required, with an addition for safety according to circumstances

Entering the table under column 3 with $\mathrm{L} = 10$ feet, and $\mathrm{P} = 15 \times 8.9 = 133.5$ tons, we find the provisional scantling is $9\frac{1}{4}'' \times 6\frac{1}{4}''$, whence $f = \frac{19898}{9\frac{1}{4} \times 6\frac{1}{4}} = 345$ lbs

Eq. 14c Putting $r = 2$, we have

$$d^3 - \frac{2 \times 19898}{345}\, d - \frac{0.913 \times 600 \times 2 \times 25 \times 25}{345} = 0,$$

$$\text{or } d^3 - 115\, d - 1985 = 0$$

Whence $d = 15''\cdot 6$ and $b = 7''\,8$.

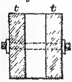
Or assuming $d = 15''\,6$, we have

Eq 14a $= \frac{1}{15.6 \times 345}\left(19898 + \frac{913 \times 600 \times 25 \times 25}{15.6}\right) = 7.8$ nearly

The scantling required for an untrussed beam is $21''\,4 \times 10''\,7$

39 A compound beam of a pair of flitches bolted together over distance pieces, would be designed in a precisely similar manner—the provisional depth would be obtained by entering the table with $5r\mathrm{T}$, and $f = \frac{\mathrm{T}}{2dt}$ on the remaining formulæ of para. 37, $b = 2t$, and $r = d - 2t$. The distance pieces must not be further apart than $10t$, and each joints in the flitches should be at one of the points of inflection, *Fig.* 5

Fig. 9



40 The use of under-trussed beams carrying the rafters directly, is not to be recommended when wooden beams of the necessary stiffness are

obtainable, or when iron girders can be had at a moderate price As in the case of pent roofs, it will frequently be found more economical when trussed beams cannot be dispensed with, to carry the rafters on purlins bearing on the trussed points Take the example given in para 38—the purlins would be spaced 8′ 4″ centre to centre, and the segments of the trussed girder would be 9′ 4″ + 8′ 4″ + 9′ 4″ = 27 feet Thrust 8·31 tons, tension on tie 8·62 tons, scantling required for a post 9′ 4″ long fixed at one end for a thrust of 8·31 tons, is say $8\frac{1}{2}$ inches square

Quantity of timber in one bay—with purlins—

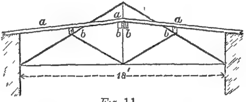
1 trussed beam,	$27' \times 8\frac{1}{2}'' \times 8\frac{1}{2}'' =$	13·6 cubic feet,	Total 30·0 cubic feet
2 purlins,	$6' \times 7\frac{1}{4}'' \times 4\frac{3}{4}'' =$	2·9 "	
6 rafters,	$26' \times 5'' \times 2\frac{1}{2}'' =$	13·5 "	

Quantity of timber in one bay when rafters are borne on the girder

1 trussed beam,	$27' \times 15\frac{1}{2}'' \times 7\frac{3}{4}'' =$	22·5 cubic feet,	Total 34·4 cubic feet
6 rafters,	$26' \times 4'' \times 2\frac{3}{4}'' =$	11·9 "	

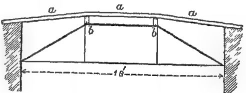
There is therefore an actual saving in this instance, if purlins are used in addition to the practical advantage of smaller timbers being required

Fig 10



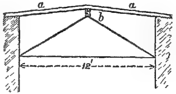
41 An economical but unsightly arrangement is shown in *Figs* 10, 11, & 12

Fig 11



The trusses may be spaced from 6 to 12 feet apart according to circumstances, and are intended to carry purlins *b*, *b*, which support the common rafters *a*, *a*

Fig 12



The arrangement in *Fig* 10 was suggested to the writer by an officer who has left the country.

The part of the truss projecting above the roof is intended to carry a ventilator *Figs* 11 and 12 are obvious modifications of the principle

NOTE A

Stresses on the members of a wooden King Post Truss when the load is uniformly distributed on the principals, *Figs* 14 and 16, *Plate* XXII At any point in the principal, w may be decomposed into $w \cos\theta$ acting at right angles to the principal, and $w \sin\theta$ acting parallel thereto AV being a continuous beam, the distribution of $W = wL$ is as follows—on either principal

At V, $\frac{3}{16}$ W $\cos\theta$

„ B, $\frac{10}{16}$ W $\cos\theta + \frac{1}{2}$ W $\sin\theta$

„ A, $\frac{3}{16}$ W $\cos\theta + \frac{1}{2}$ W $\sin\theta$

Total resultant, $\begin{cases} W\cos\theta \text{ at right angles to principal,} \\ W\sin\theta \text{ parallel to principal,} \end{cases}$

equivalent when combined to W (in a vertical direction)

The distribution of the normal wind pressure at the trussed points is similarly

at V, $\frac{3}{16}$ W′,

„ B′, $\frac{10}{16}$ W′,

„ A′, $\frac{3}{16}$ W′,

and the resultants are

at A″, $R' = W' \frac{\sec^2\theta}{4}$,

„ A′, $R' = W' - R''$

As an example (*see Plate* XXII), diagrams have been constructed of two king post trusses, $L = 10$ feet, pitches 30° and 60°, $w = w' = 40 \times 5 = 200$, $W = W' = 2{,}000$,

$w = 150$, $w' = 250$, $W \cos 30° = W \sin 60° = 1{,}732$

$W \sin 30° = W \cos 60° = 1{,}000$

Load	Value	Reference to figure	30° lbs.	60° lbs	Direction
Load at A″,	$\frac{3}{16}$ W $\cos\theta$	$a''a''$	325	188	⊥ A″ V
Thrust at „	$\frac{1}{2}$ W $\sin\theta$	$a''b''$	500	866	‖ „
Load „ B″,	$\frac{10}{16}$ W $\cos\theta$	$b''\beta''$	1,082	624	⊥ „
Thrust „ „	$\frac{1}{2}$ W $\sin\theta$	$\beta''c''$	500	866	‖ „

Load	Value	Reference to figure	30° lbs	60° lbs	Direction
Loads at V,	$\frac{5}{16}$ W $\cos\theta$	$c''\delta''$	325	188	$\perp$ A″ V
„ „ „	W	$\delta''\delta'$	150	150	Vertical
„ „ „	$\left\{\begin{array}{l}\frac{5}{16}\text{ W }\cos\theta\\ +\frac{3}{16}\text{ W}\end{array}\right.$	$\delta'c'$	700	563	$\perp$ A′V
Thrust „ B′,	$\frac{1}{2}$ W $\sin\theta$	$c'\beta'$	500	866	‖ „
Loads „ B,	$\left\{\begin{array}{l}\frac{10}{16}\text{ W }\cos\theta\\ \frac{10}{16}\text{ W}'\end{array}\right.$	$\beta\,b'$	2,332	1,874	$\perp$ „
Thrust „ A′,	$\frac{1}{2}$ W $\sin\theta$	$b\,a'$	500	866	‖ „
Loads „ A′,	$\left\{\begin{array}{l}\frac{3}{16}\text{ W }\cos\theta\\ +\frac{3}{16}\text{ W}'\end{array}\right.$	$a'a'$	700	563	$\perp$ „
Reaction at A′,	$\text{W}+\frac{\text{W}+\text{W}'}{2}$	A′a'	2,200	2,200	Vertical
	$\text{W}'-\text{R}''$	A′m	1,833	nil	$\perp$ A′V
Load „ M,	W′	$m'm''$	250	250	Vertical
Reactions „ A″,	$\text{R}''=\text{W}'\,\frac{\sec^2\theta}{4}$	m''A″	667	2,000	$\perp$ A′V
„ „ „	$\text{W}+\frac{\text{W}+\text{W}'}{2}$	A″a''	2,200	2,200	Vertical

The following trigonometrical expressions for the maximum stresses on the principal members of the truss have been deduced from the diagrams *Figs* 13 and 15 in the Plate. The expressions are complicated, and it will in general be found less troublesome to construct a diagram than to work them out

$$\left.\begin{array}{l}\text{From } \theta = 0^\circ \text{ to } \theta = 38^\circ\,20' \quad \text{T}' = b'p' = \\ \text{W}\,\frac{\operatorname{cosec}\theta}{2}\left(1+\frac{5\cos^2\theta}{8}\right)+\frac{\text{W}+\text{W}'}{2}\operatorname{cosec}\theta+\text{W}'\,\frac{\cot\theta}{4}\left(3\tfrac{1}{4}-\sec^2\theta\right),\end{array}\right\}(15)$$

$$\left.\begin{array}{l}\text{From } \theta = 38^\circ\,20' \text{ to } \theta = 90' \quad \text{T}'' = b''p'' = \\ \text{W}\,\frac{\operatorname{cosec}\theta}{2}\left(1+\frac{5\cos^2\theta}{8}\right)+\frac{\text{W}+\text{W}'}{2}\operatorname{cosec}\theta+\text{W}'\,\frac{\sec\theta\operatorname{cosec}\theta}{4}\end{array}\right\}(15a)$$

Equation (15) gives the thrust at A, from which point it decreases uniformly along AB to B, where its value below the purlin is $= \text{T} - ab$

$$= \text{T} - \tfrac{1}{2}\,\text{W}\sin\theta$$

At the centre of the lower section of principal,

$$\text{the thrust} = T' \text{ or } T'' - \tfrac{1}{4} W \sin\theta, \qquad (15b)$$

$$H' = p'm' = W\frac{13\cot\theta}{16} + \frac{w + W'}{2}\cot\theta + W'\frac{\operatorname{cosec}\theta}{4}\left(2\tfrac{1}{4} - \tan^2\theta,\right) \qquad (15c)$$

$$S' = p'q' = \frac{5\operatorname{cosec}\theta}{16}(W + W'\sec\theta), \qquad (15d)$$

$$K = q'q'' = \frac{5\operatorname{cosec}\theta}{8}\left(W + W'\frac{\sec\theta}{2}\right) + w', \qquad (15e)$$

NOTE B

The stresses on the members of a simple symmetrical truss, when the load is uniformly distributed, may be obtained in a similar manner, *see* diagram, *Figs* 17 and 18 The distribution of the permanent load is as follows on either principal,

at V, $\frac{1}{2}$ W cos θ,

„ A, $\frac{1}{2}$ W cos θ + W sin θ,

and the distribution of the normal wind pressure on VA′ is $\frac{1}{2}$ W′ at V and A′, the resultants remaining as before

Taking the same example, but putting w = 400, we have,

Load	Value	Reference to figure	30° lbs	Direction
Load at A″,	$\frac{1}{2}$ W cos θ	$a''a''$	866	⊥ A″V.
Thrust at „	W sin θ	$a''b''$	1,000	‖ „
Load „ V,	$\frac{1}{2}$ W cos θ	$b''\beta''$	866	⊥ „
„ „ „	w	$\beta''\beta'$	400	Vertical
„ „ „	$\frac{1}{2}$ W cos θ	$\beta b'$	866	⊥ VA′
„ „ „	$\frac{1}{2}$ W′		1,000	
Thrust „ A′,	W sin θ	ba	1,000	‖ „
Load „ „	$\frac{1}{2}$ W cos θ	aa'	866	⊥ „
„ „ „	$\frac{1}{2}$ W′		1,000	
Reaction at A′,	W + $\frac{1}{2}$ w	a'A′	2,200	Vertical
„ „ „	W′ − R″	A′m	1,333	⊥ VA′
„ „ A″,	$R'' W' \frac{\sec^2\theta}{4}$	mA″	667	„ „
„ „ „	W + $\frac{1}{2}$ w	A″a''	2,200	Vertical

The following expressions for the several stresses may be deduced from the diagram, *Fig* 17

$$T' = b'p = \tfrac{1}{3}\,W\,\cos\theta\cot\theta + \tfrac{1}{2}\,w\,\mathrm{cosec}\,\theta + \tfrac{1}{4}\,W'\cot\theta\,(2 - \sec^2\theta), \quad (16)$$

$$T'' = b''p = \tfrac{1}{2}\,W\,\cos\theta\,\cot\theta + \tfrac{1}{2}\,w\,\mathrm{cosec}\,\theta + \tfrac{1}{4}\,W'\sec\theta\,\mathrm{cosec}\,\theta, \quad (16a)$$

T'' is always greater than T'

T = thrust at A, from which point it uniformly decreases to $T - ab$
$= T - W \sin\theta$ at V

st at centre of $A'V = T'_m = \tfrac{1}{2}\,W\,\dfrac{\cos 2\theta}{\sin\theta} + \tfrac{1}{2}\,w\,\mathrm{cosec}\,\theta + \tfrac{1}{4}\,W'\cot\theta\,(2 - \sec^2\theta)$, (16b)

$$H = \tfrac{1}{3}\,W\cot\theta + \tfrac{1}{4}\,W'\,\mathrm{cosec}\,\theta\,(1 - \tan^2\theta) + \tfrac{1}{2}\,w\cot\theta, \quad (16c)$$

NOTE C

The expression given in the former article* (Eq 7B,) for the most economical arrangement of the beams of a flat roof, omits consideration of the ends of the beams resting on the side walls, and assumes that the space to be roofed is infinitely long This is not strictly accurate, but the difference is not important, the table, page 563,* may be accepted, if a small addition is made to the tabular numbers

Calling the lengths of beam resting on walls a, and the total lengths of the beam $= L + a$, Equation 7B becomes,

$$S = 0\,557\,L^{\frac{1}{3}}\,(L + a)^{\frac{1}{3}}\,\left(\frac{r}{R}\right)^{\frac{1}{3}}\,\left(\frac{V}{r}\right) \quad . \quad . \quad (17),$$

or a close approximation to S may be obtained by multiplying the tabular numbers by $1 + \dfrac{a}{2L}$

To allow for the end walls, call total length of the room l, and the number of bays in the roof n, then the number of beams $= n - 1$, and the central spacing of the beams $= l - n = ln^{-1}$

Also we have the cost of any beam, the scantling of which has been fixed by the deflection formula, equal to

$$\frac{bd}{144}\;v\,(L + a)$$

$$= cvr^{-1}\,w^{\frac{1}{3}}\,L^{\frac{1}{2}}\,(L + a), \text{ where } c = \sqrt{\frac{25}{E_d}} - 144$$

We have then the cost of all the beams in the roof

* No LVII, Professional Papers on Indian Engineering, (Second Series)

$$= (n - 1)\,(\mathrm{L} + a)\,c\mathrm{VR}^{-\frac{1}{2}}\,w^{\frac{1}{2}}\,l^{\frac{1}{2}}\,\mathrm{L}^{\frac{3}{2}}\,n^{-\frac{1}{2}}$$

and the cost of all the burgahs in the roof (on the assumption that their bearing is equal to the central spacing of the beams)

$$= n\mathrm{L} \times cvr^{-\frac{1}{2}}\,w^{\frac{1}{2}}\,l^{\frac{5}{2}}\,n^{-\frac{3}{2}} = cvr^{-\frac{1}{2}}\,w^{\frac{1}{2}}\,l^{\frac{5}{2}}\,\mathrm{L}n^{-\frac{1}{2}} = cn^{-\frac{1}{2}}$$

Putting $\mathrm{A} = c\mathrm{VR}^{-\frac{1}{2}}\,w^{\frac{1}{2}}\,l^{\frac{1}{2}}\,\mathrm{L}^{\frac{3}{2}}$ and $\mathrm{B} = c\mathrm{VR}^{-\frac{1}{2}}\,w^{\frac{1}{2}}\,l^{\frac{1}{2}}\,\mathrm{L}^{\frac{3}{2}}$ } in the expressions for the cost of the beams

The total cost of the timbering is (omitting wall plates as well as the ends of the burgahs resting on the end walls)

$$(\mathrm{A} + \mathrm{B})\,n^{\frac{1}{2}} - (\mathrm{A} + \mathrm{B})\,n^{-\frac{1}{2}} + en^{-\frac{1}{2}} = u$$

Equating the first differential coefficient to zero, and clearing of negatives and fractional indices, we have

$$n = \frac{-1 \pm \sqrt{1 + \frac{12e}{\mathrm{A}+\mathrm{B}}}}{2}$$

$$\text{or } n = \pm \sqrt{\left\{0\cdot25 + \frac{3\,l^{2}}{(\mathrm{L} + a)\,\mathrm{L}^{\frac{1}{2}}}\;\frac{v}{\mathrm{V}}\;\left(\frac{\mathrm{R}}{r}\right)^{\frac{1}{2}}\right\}} - 0\cdot5,$$

and $\qquad s = l - n, \qquad$. (17a),

If it be desired to have n an exact integer, first calculate n, assigning any convenient value to $\frac{\mathrm{R}}{r}$, take the nearest integer to n which call n_1 then we have the corrected value of

$$\frac{\mathrm{R}}{r} = \left\{\frac{n_1\,(n_1 - 1)\,(\mathrm{L} + a)\,\mathrm{L}^{\frac{1}{2}}}{3\,l^{2}}\;\frac{\mathrm{V}}{v}\right\}^{2} \qquad (17b)$$

This, however, is an unnecessary refinement, and may not give a convenient or economical value to R and r, it will suffice to make the number of bays the nearest whole number to n as obtained from (17a), retaining the values of R and r assumed in the first instance

The identity of Equations (17) and (17a) is readily established,

put $q = \frac{v}{\mathrm{V}}\;\left(\frac{\mathrm{R}}{r}\right)^{\frac{1}{2}}$

we have

$$s = l - n = l \times \frac{2}{\pm\sqrt{\left\{1 + \frac{12\,l^{2}}{(\mathrm{L}+a)\,\mathrm{L}^{\frac{1}{2}}}\cdot q\right\}} - 1}$$

(multiplying and dividing the denominator by l), this becomes

eet, d in inches, P in tons

$= 2\ 7$ tons

Under lengt po

$= 2\ 304$

$= 1\ 024$

$= 0\ 576$

Explanation —For permanent structures, enter the appropriate column under the length with 10 times the load ($P = 10\ T$), the side of the required square post will be found in the left hand column For rectangular posts, let the assigned ratio of the sides be dd' b, d being the least width, (unless the post is free to bend in only one direction,) then enter with $P = 10\ T \times d' - b$, the required width d will be found as before, and $b = d \times b - d'$ For other kinds of timber, enter with $P = 10\ T \times 2\ 7 - f$, (in tons per square inch)

Side of square post, inches	Sh Po d ≻ 2 (to	9 feet			10 feet			11 feet			12 feet		
		1	2	3	1	2	3	1	2	3	1	2	3
2	6	0 23	0 49	0 86	0 19	0 40	0 70	0 15	0 34	0 59	0 13	0 28	0 50
2½	5	0 54	1 11	1 99	0 45	0 91	1 60	0 37	0 82	1 39	0 31	0 68	1 18
3	5	1 11	2 30	3 92	0 91	1 90	3 28	0 76	1 60	2 78	0 64	1 40	2 38
3½		2 03	4 25	6 89	1 67	3 53	5 81	1 39	2 97	4 94	1 17	2 58	4 26
4		3 41	6 90	11 03	2 80	5 80	9 39	2 34	4 90	8 06	1 98	4 20	6 98
4½		5 36	10 76	16 60	4 42	9 05	14 27	3 71	7 75	12 35	3 15	6 62	10 77
5		7 97	15 60	23 57	6 61	13 20	20 15	5 55	11 30	17 84	4 73	9 80	15 65
5½		11 40	21 86	32 17	9 46	18 64	28 17	8 00	16 01	24 76	6 84	13 92	21 87
6		15 72	29 40	42 33	13 13	25 60	37 38	11 11	21 70	33 10	9 51	19 10	29 42
6½	1	21 10	38 53	54 29	17 71	33 85	48 35	15 05	29 04	43 13	12 91	25 13	38 56
7	1	27 52	49 10	67 92	23 21	42 80	60 97	19 78	37 50	54 76	17 01	32 90	49 27
7½	1	35 15	61 38	83 18	29 8	53 84	75 20	25 48	47 43	67 93	22 00	41 94	61 52
8	1	44 15	75 20	99 90	37 56	66 40	90 91	32 26	58 80	82 71	27 96	52 30	75 26
8½	1	54 48	91 11	118 97	46 56	80 94	108 99	40 14	72 08	99 74	34 88	64 37	91 27
9	2	66 19	108 20	138 85	50 89	96 80	127 90	49 24	86 80	117 63	42 94	77 70	108 15
9½	2	79 49	127 20	160 48	68 65	114 40	148 60	59 65	102 90	137 33	52 16	92 70	126 82
10	2	94 29	147 80	184 14	81 71	133 60	171 32	71 28	120 80	159 11	62 76	109 30	147 58
10½	2	110 35	169 80	209 47	96 34	154 20	195 85	84 35	140 06	182 72	74 24	127 20	170 28
11	3	128 67	194 40	235 26	113 65	177 50	220 74	99 03	162 02	206 67	87 45	147 80	193 18
11½	3	148 21	219 90	264 85	130 33	201 70	249 72	114 99	181 80	231 88	101 86	169 30	220 54
12	3	169 33	246 80	293 65	149 54	227 30	277 71	132 42	309 10	261 99	117 67	192 20	246 70

Computed by LALLA GOORSAHAI,

Lahore

$$s = \frac{l}{l} \quad \frac{2}{\pm \sqrt{\left\{ \frac{1}{l^2} + \frac{12}{(L + a) L^{\frac{1}{4}}} \quad q \right\}} - \frac{1}{l}},$$

if we increase l without limit, $\frac{1}{l}$ and $\frac{1}{l}$ ultimately vanish, and

$$s = 2 \pm \sqrt{\frac{12}{(L + a) L^{\frac{1}{4}}}} \quad q = L^{\frac{1}{4}} (L + a)^{\frac{1}{2}} \quad \left(\frac{v}{R}\right) \quad \left(\frac{V}{r}\right) \frac{1}{\sqrt{3}}$$

which is Eq 17a

If we put $a = 0$,

this becomes $s = \frac{L^{\frac{3}{4}}}{\sqrt{3}} \quad \left(\frac{v}{R}\right)^{\frac{1}{4}} \quad \left(\frac{V}{r}\right)^{\frac{1}{2}}$, which is Eq 7B of the former Article

Approximate values of $s = l - n$ from Eq (17a) $R = 2$, $r = 1.5$, $V =$ Rs 2-8-0, $v =$ Rs 2-0-0, $a = 3$

Length	Span 16 feet	Span 20 feet	Span 25 feet
16 feet	7 30 (2 bays)		
20 feet	7 02 (3 bays)	8 38 (2 or 3 bays)	
25 feet	6 82 (4 bays)	8 09 (3 bays)	9 65 (3 bays)
36 feet	6 58 (6 bays)	7 78 (5 bays)	9 22 (4 bays)
40 feet	6 52 (7 bays)	7 69 (5 bays)	9 11 (4 or 5 bays)
Infinite.	5 67	6 42	7·58

W H M

No CXCII

WORK AND WAGES *

A Review by an Executive Engineer

THIS book is written by the son of the celebrated Engineer Contractor, from materials collected by the father, and augmented by the industry and observation of the son It is dedicated to the author of "Tom Brown's School Days," and is prefaced by a few observations of the late Sir Arthur Helps who testifies to its importance It is a small pocket volume of 284 pages of large type, and costs only a few shillings But its value is priceless To the formation of a theory of industrial law worthy the name of science it furnishes a contribution of extraordinary value. It was first published in 1872, had reached its 5,000 in the following year, and has since gone through several editions It not only records the precious experience of a long busy and unique life, but is a rich store house of valuable *data* collected from many reliable sources and brought together in methodical order The immense range of the late Mr Brassey's dealings will be appreciated by the simple statement, that he expended over the four quarters of the world on his own contracts no less than seventy-eight millions sterling, or an eighth part of the present capital of all the English Railways In fact such a field for investigation in industrial philosophy has never before been offered to the world in so compendious a form The volume thus contains ample food for thought, and is eminently suggestive More especially is there much in it to interest Indian Engineers, whose vast and varied sphere of labor is replete with

* On Work and Wages, by Thomas Brassey, M P , Bell and Daldy, 1873 Price 7s 6d

numerous social problems of the most intricate and obscure kind It is proposed to review it at some length in these pages, with the hope that Indian Engineers may be able to furnish information of a similar kind

Mr Brassey divides the subject into several convenient heads, some only of which can be here considered In every case he illustrates the subject by numerous practical examples culled from many sources Of these we have only room to record the most striking The heads under which the whole subject can be most conveniently reviewed are—

I Demand and supply
II Dear labor stimulates invention
III Rates of work not in proportion to rates of wages
IV Hours of labor
V Wages, their rise and fluctuations
VI The industrial capabilities of different nations compared, and
VII Piece work

The recognition of the rights of free labor came late in the history of the world To the Greeks and Romans it was unknown For ten centuries after the third the church was its best protector For the next five centuries the Parliaments, the Legists, and the Lawyers did much to secure its liberty. Subsequently the mighty force of public opinion removed one by one the working man's fetters, until we reach the almost perfect freedom of the present day Nor is this all The laborer by uniting with his fellows endeavoured to quicken the ameliorating process And this is not a thing only of the present time "The guilds of the middle ages were but the forerunners of the Trades Unions of to-day, and the strikes of modern times have had their counterpart in the Jacquerie riots of the fourteenth century." But the potency of Trades Unions has, Mr Brassey considers, been greatly exaggerated Nine hundred thousand men are employed in the building trades of England not more than one-tenth of these are members of Trades Unions And so little has this small proportion been able to effect in equalizing their wages, that the wages of masons, bricklayers and carpenters, each vary from $4\frac{1}{2}d$ to $8\frac{1}{2}d$ per hour Or to give another instance after protracted struggles in various trades against reduced wages at Preston and at Wigan in 1852, 1853, 1865 and 1868, the workmen were compelled in every case to accept the original proposal of their employers * Though Mr Brassey plainly points out

* "The success which marked Mr Brassey s career has become matter of notoriety, but no em

the harm wrought by Trades Unions, he at the same time shows the good they have done, and are capable of doing when confining themselves to their legitimate spheres of operation. But, for them India is not yet ripe. "When in any country," says Adam Smith, "the demand for those who "live by wages is continually increasing, the workmen have no occasion "to combine to raise their wages. The demand increases necessarily with "the increase of the revenue and stock of every country, and cannot possi- "bly increase without it. The condition of the laboring poor and of the "great body of the people is healthy in a stationary, and miserable in a "declining, state. The progressive state is in reality the cheerful, and the "hearty state in all the different orders of society. The stationary is "dull, the declining melancholy." These axioms of the great economist are abundantly verified by the facts adduced by Mr. Brassey, some of which are well worthy of being here recorded under.

I. Demand and Supply.—When the Grand Trunk Railway was being constructed in Canada, the late Mr. Brassey sent out a great number of operatives from England. On landing in Canada, they received for doing the same work 40 per cent more than they had been earning, although the cost of living in Canada was not greater than in England. The obvious cause of this was, that the supply of such labor was abundant at Home, while in Canada skilled artizans were comparatively rare. The fall in wages which follows a commercial panic, when production is diminished and employment is scarce, proves how closely the rate of wages fluctuates with the varying relations between demand and supply. When the English railway panic took place in 1847-48, even the common laborers employed on the Eastern Union Railway accepted lower wages. In 1849, men who on the North Staffordshire line shortly before the panic had been paid 3*s*.6*d* a day, only earned half a crown on the Royston and Hitchin line.

The following table gives the weekly wages earned by men employed on railway works from 1843 to 1869.

"ployer ever dealt more liberally with labor. The almost invariable result of the commencement "of Railway operations in any country in England, or in any country abroad, was a rise in the pre- "valent rate of wages. On one occasion an estimate was submitted to him for a contract, for which "a sharp competition was expected. The prices had accordingly been cut down to an unusually low "figure. He thereupon asked 'How it was proposed to carry on the work for such inadequate "prices'? In reply it was stated that the calculation was based on the assumption that a reduction "of wages could be negotiated. On receiving this explanation, he desisted from all further examina- "tion of the estimate, saying that if business could only be obtained by screwing down wages, he "would rather be without it,'" pages 8 and 9.

	Periods									
	1843	1846	1849	1851	1855	1857	1860	1863	1866	1869
	s	s	s	s	s	s	s	s	s	s
Masons, ...	21/-	33/	24/-	21/-	25/6	24/-	22/6	24/-	27/-	27/-
Bricklayers, ...	21/	30/-	24/-	21/-	25/6	22/6	22/6	24/	27/-	25/6
Carpenters and Blacksmiths,	21/	30/-	22/6	21/-	24/	22/6	22/6	24/-	25/6	24/-
Navvies, Getters (Pickmen), ..	16/6	24/-	18/	15/-	19/	18,	17/	19/-	20/	18/-
" Fitters (Shovellers), .	15/-	22/6	16/6	14/-	17/-	17/-	16/-	17/-	18/-	17/-
Cost of labor only per cubic yard										
Of Brickwork, .. .	2/3	3/9	2/9	2/3	2/6	2/6	2/4	2/6	2/9	2/6
Of Earthwork, .. .	-/4½	-/7½	-/5	-/4	/5¼	/5¼	/5	/5½	-/5¾	-/5½

The following note on the railway *furore* by one of Mr Brassey's correspondents will be interesting

"Lancaster and Carlisle, Caledonian, Trent Valley, North Staffordshire, Eastern Union Railways in construction Height of the railway mania. Demand for labor excessive, very much in excess of supply Beer given to men as well as wages Look outs placed on the roads to intercept men tramping, and take them to the nearest beer shop to be treated and induced to start work Very much less work done in the same time by the same power Work going on night and day, even the same men working continuously for several days and nights Instances recorded of men being paid 47 days in one lunar month Provisions dear Excessively high wages, excessive work, excessive drinking, and indifferent lodgings caused great demoralization"

The activity of the Welsh Iron Manufacture of the present day is remarkable

The following table shows the comparative earnings of the workmen in the years 1842, 1851 and 1869

Comparative earnings of Workpeople employed in Iron Manufacture

Occupation,	1842		1851		1869	
	Price per ton	Wages per week	Price per ton	Wages per week	Price per ton	Wages per week
	£	s	£	s	£	s
Miners, ...	..	10/-to16/	..	11/ to16/	..	12/- to 18/-
Colliers, ...	..	14/-to16/	..	15,-to18/-	..	16/- to 20/-
Furnaces,						
Founders, ...	4/ /-	17/-to18/-	3/-	25' to29/	1/$\frac{8}{16}$	27/- to 30/-
Fillers, . ..	..	17/ to18/-	3/-	25/ to29/	1/$\frac{8}{16}$	27/ to 30/-

Occupation	1842 Price per ton.	1842 Wages per week	1851 Price per ton	1851 Wages per week	1869 Price per ton	1869 Wages per week
	£ s	s	£ s	s	£ s.	s
Cinder fill, ..	3/6	15/-to16/	-/2½	21/-to24/-	1/$\frac{2}{10}$	20/-to22/6
Laborers, .	..	10/6		10/6	..	11/6to12/6
Forge, ... Puddlers, ..	Pig-iron nil, metal 106/ 1st hand	Share 16/ to16/6 21/-to22/-	Pig iron 90/- metal nil 1st hand	Share 16/-to18/- 22/-to25/-	4/11, 5/11 and 4/- 1st hand	Share 18/ to24/- 28/-to32/-
Laborers, ..	.	10/6	..	10/6	.	10/6to18/-
Girls, ...	..	nil	..	4/9		5/6 to6/6
Mills	Bar iron	.	Rails	..	Rails	.
Heaters, ...	1/5	24/-to26/-	First heater 1/1 second heater -/6½	25/-to27/- 35/-to37/-	First heater-/10½ second heater-,5¼	25/-to28/6 35/-to40/-
Rollers, &c, ..	1/8½ contract	..	10/3	..	7¾	Roller,50/- Rangher 40/-each
Laborers, .. .	.	10/6	..	10/6	..	11/-to12/6
Girls, ...	..	4/9	.	4/9	..	5/6 to 8/-
Carpenters, ..	..	12/6	.	13/ to14/-	..	13/-to16/6
Pattern makers,	..	13/-to14/-	..	13/-	..	13/6 to19/-
Fitters, .. .	..	12/-to14/	..	12/-to14/-	..	13/-to19/-
Blacksmiths, ..	..	12/-to15/6	..	contracts	..	14/-to22/6
Masons, ...	..	12/-to15/-	..	15/-	..	14/- to 20/

Let us now take an instance or two from Foreign countries At Loben in Silesia, the erection of a factory in an agricultural district caused a rise in laborers wages (which were only 6*d* a day for men and 3*d* for women) of 50 per cent for the former, and 100 per cent for the latter Owing to the limited supply of skilled labor the wages of artizans in all newly settled countries are higher than the rate in England. A fitter whose annual salary in England would be £78, commands £200 a year at Rosario in the Argentine Republic Engineers of steamers on the River Plate, are paid £240 a year, or more than double the rate they would obtain in England

The following observations of Mr. Brassey are of great interest to Indian Engineers.—

Since 1853 we have subscribed no less than 40 millions of pounds for Indian Railways A considerable portion of this sum has been paid to native laborers, and the result has been that in the districts traversed by these railways, wages have advanced within a short time no less than 100 per cent. In consequence of the great demand for workmen, the price of labor has increased to an extent still more marvellous in Bombay

Wages in that Presidency are now two or three times higher than in Bengal and the Punjab

In a paper furnished to the Select Committee on East India Finance by Sir Bartle Frere, some remarkable examples are given of a rise in wages in consequence of the increased competition for labor for railways and other great public works

The following table shows the variations in the average monthly wages of a carpenter in Bombay —

	s	d
1830-39,	30	4
1840 49,	28	10
1850-59,	32	7½
1863,	58	0

The following table shows the wages of a coolie at the same periods —

	s	d.
1830-39,	14	9½
1840-49,	12	8¼
1850-59,	14	2
1863,	27	0

Everywhere in the vicinity of railway works the Collectors remark on their great effect in raising wages. The practice of promptly paying for all labor in liberal money wages caused an important social revolution in the habits of all who live by labor, even at a great distance from the railway works. The laborers often travelled from their homes 200 miles to obtain work so paid, returning home at the harvest time.

The increase in wages in Bombay had increased the number of consumers of superior qualities of grain and meat The increased consumption had raised the cost of living The advance in the cost of living had had the effect of raising the rate of wages for with their former earnings the people could no longer have provided themselves with the necessaries of life

Moreover, the increased external trade of Bombay, the influx of money for the purchase of commodities, and the consequent depreciation in the purchasing power of bullion, and the increased demand for labor, had by their combined influence produced an astonishing advance of wages in Bombay, as compared with Bengal.

The following table shows the difference between the rates in Bengal and Bombay —

	In Bengal per month Rs	In Bombay per month Rs.
Carpenters,	9	25
Masons,	$5\frac{4}{16}$	21
Laboring coolies,	6	$9\frac{1}{16}$
Horse keepers,	5	$8\frac{2}{16}$

It is impossible to produce a more striking example of the effect of an increased cost of living, and an increased demand for labor in raising the rate of wages

In pointing out the intimate relations which exist between capital and labor Mr Brassey forcibly remarks " Pernicious in their social tendency

and scientifically inaccurate are the doctrines of those who seek to persuade the working people that the capitalists are their natural enemies" And he gives a striking though melancholy instance

At the head of the Gulf of Bothnia, far removed from the enjoyments and advantages of European civilization, there dwells a community of peasants, on whose dreary abode for a considerable part of the year the sun never shines In frost and snow and darkness throughout their long winter, these unfortunate people are engaged in felling and sawing timber and making tar When the spring at length returns, and the seas so long frozen up are once more navigable, a few mercantile agents pay them an annual visit and purchase the timber and the tar which have been prepared in the previous winter The purchase is effected not by giving money in exchange, but by a system of barter, in which the peasants, innocent of the value of their own labor, are hardly dealt with They receive a supply of meal barely sufficient to maintain them during the coming winter, and a limited quantity of cast-off clothing, purchased perhaps from the old clothes dealers of London Many of these poor people have never tasted meat, and as they are always in debt to the merchants for the supplies of meal which they have accepted in advance, they are not in a position to negotiate, as independent parties to the transaction, for more liberal terms of payment During the summer the people work for a great many hours, but from imperfect nourishment their physical strength does not enable them to put forth the same exertions as an English workman.

"To what," says Mr Brassey, "shall we mainly attribute their pitiable "condition? To the entire absence of accumulated capital, and the depen-"dance of the peasantry on employers who are too poor to be generous, and "in whom the desire to make the most of their small capital has altogether "extinguished the virtue of charity and the spirit of justice"

Numerous similar illustrations are afforded in India Even now there are many parts where the plight of the inhabitants is as pitiable as that of the peasants in the Gulf of Bothnia The condition of others has been improved by the influx of capital supplied both by Government and by private individuals Not many years ago in a certain delta the villagers were so poor that the women had to remain *in puris naturalibus*, and could never leave their miserable homes except during the hours of darkness Large sums of money were subsequently poured into the district to create irrigation works, and completely changed the condition of the residents Note similar facts in Hunter's "Orissa" and "Rural Bengal." Observe also such parts of India into which European enterprise and capital have entered in the shape of Planters—owners of tea, coffee, and indigo estates There on each estate, £1,000 are commonly paid away monthly in wages to the coolies The improvement thus effected in their condition is clearly perceived by those who work in their districts,

and the advantage to the laborers in every way by this arrangement is obvious. The policy of statesmen in the interests of the Natives alone is clearly to encourage such European "interlopers." Yet how frequently are they obstructed through an erroneous and short sighted policy. The example of these Europeans has already communicated itself to the Natives. In some parts the latter have amassed money with which they have purchased virgin land, and have opened and planted it with indigo, coffee, and tea. The Government land sales in many hill districts are as keenly competed for by Natives as by Europeans. The spread of this spirit amongst our Arian brethren is greatly to be desired.

II. Dear labor stimulates invention.—It used to be thought that the substitution of machinery for hand labor, and the consequent diminution in the number of hands employed, was a change prejudicial to the interests of labor. But M. Michel Chevalier truly says, that machinery can alone enable dear to compete with cheap labor, and that England, which makes 57 per cent. of the textile fabrics of Europe, owes her superiority entirely to the extensive use of machinery.

The following table shows how machinery augments the productive powers as well as the earnings of the operatives:—

Years.	Work turned off by one spinner per week		Wages per week.			Hours of work per week	Prices from Greenwich Hospital records		Quantities which a week's nett earning would purchase	
	lbs	Nos	Gross	Pieces	Nett		Flour, per sack	Flesh, per lb	lbs of flour	lbs of flesh.
			s	s	s		s	s		
1804	12	180	60/-	27/6	32/6	74	83/-	6/-to7/-	117	62½
„	9	200	67/6	31/-	36/6	74	88/-	6/-to7/	124	73
1814	18	180	72/-	27/6	14/6	74	70/6	8/-	175	67
	18½	200	90/-	30/-	60/-	74	70/6	8/-	239	90
1833	22½	180	54/8	21/-	33/8	69	45/-	6/-	210	67
„	19	200	65/3	22/6	42/9	69	45/	6/	267	85

In England, by the introduction of the locomotive, it is practicable to carry a load of earth to a greater distance for the same money. In the strike of 1851, Mr. Nasmyth by mechanical contrivances reduced the 1,500

men in his employ by one-half, and very much increased his profits In Denmark, an improved system of working reduced the cost of railway construction by 35 per cent At the present time in Australia, though the rate paid for labor is 20 per cent higher, railways are made much cheaper than formerly, owing to greater skill in construction, and from machinery being employed to do work formerly directly performed by men and horses It would be very interesting to know the details by which this economy has been effected Mr Brassey does not give them In America, wages are so high that cast is extensively used for wrought-iron To such a perfection has its manufacture been brought, that the American cast-iron wheels withstand the great shocks to which they are subjected by the imperfectly laid railroad, exposed as it is to peculiar climatic influences, better than wrought-iron wheels procured from England Even rain water pipes are so beautifully cast that they are only $\frac{1}{8}$ of an inch thick, whereas in England they would be $\frac{3}{8}$ of an inch thick. In the hardware trade of the United States the wages of the workmen are the double of those in England but labor saving appliances have enabled the United States to export hardware goods largely into countries in which the pay of the artizans is only a quarter of the wage paid in America They send their spades, shovels, axes, coopers tools and pumps to England, although their raw material and wages are twice as dear

Returning to England, we may note two remarkable facts The re-manufacture of iron rails in 1860 cost £7 15*s* per ton in 8 years by improvements in the machinery the price was reduced to £7, or by 10 per cent, although in both cases the old rails were charged at the same rate And though wages have remained *in statu quo*, locomotives cost $7\frac{1}{2}$ per cent less than they used to do, owing to the application of improved machinery

In India is not our experience altogether different? The use of machinery seldom seems to answer The machine whatever it is must be simple, almost self-workable, and little liable to get out of order It needs close and good European supervision. Natives seem to have no genius for it They never come to love the machine as an European mechanic does The keeping of it in constant order and cleanliness never strikes them as being essential to its economical and effective working Work turned out by machinery is thus generally more expensive than that produced in the ordinary native way Even on such a simple thing as a

pump, how soon it gets out of order in a native's hands But in the matter of *tools* the results are more favorable For example native carpentry is greatly improved and expedited by good and suitable tools Bricks are more quickly and better laid where the workmen, are supplied with proper implements. Mortar is better ground and mixed when certain simple mills are employed But in the use of complicated machinery, where the intelligence of the native mechanic forms an integral part of the performance, the result is generally unsatisfactory Babbage has at great length clearly shown that in order to succeed in a manufacture it is necessary not merely to possess good machinery, but that the domestic economy of the factory should be most carefully regulated *

It will be apposite here to quote from the *Pioneer* some remarks made by two competent authorities on the relative advantage of employing saw machinery in converting timber into scantlings They were made on a paper read before the recent Forest Conference at Simla Mr Guilford L Molesworth, Consulting Engineer for (State) Railways—compared machinery with hand work, and showed that the financial success of the former was not so great as was generally supposed, instancing brickmaking as an example Passing on to saw machinery, he compared circular with upright saws. It was probable he said that in the future the hand saw would be used for the conversion of large timber, though it was not yet sufficiently perfected for that purpose In forests where skilled labor was hard to obtain, it would be difficult to introduce what would be theoretically the more perfect machine for working Dr Brandis remarked that there were two essential conditions for the success of machinery, *first*, that the forest must contain mature timber in compact masses, and *secondly*, that hand labor must be uncertain or very expensive under these conditions saw machinery became a necessity

III Rates of Work not in proportion to rates of Wages —Mr Joseph Hume in 1825 thus spoke in the House of Commons "He had heard "it stated that low wages were a good thing This he denied Low wages "tended to degrade the laborer It was the high wages which the English artizan received, compared with the miserable pay of the Irish "laborer, which made the former so superior in energy " And Mr Fawcett observes that, "the cost of labor is determined by the amount of "work which is really done for the wages Many of our laborers can

* Economy of Manufactures, by C Babbage, 1832, page 195

"barely obtain the necessaries of life, and we can all appreciate the false "economy which would be practiced if a horse was so much stinted in "food that he could only do half as much work as he would be able to "perform if he were properly fed"

But Mr Brassey goes further He maintains that daily wages are no criterion of the actual cost of executing works or of carrying out manufacturing operations On the contrary, he proves by numerous examples, that there is a most remarkable tendency to equality in the actual cost of work throughout the world, and that it is quite possible for work to be executed more cheaply by the same workmen notwithstanding that their wages have largely increased "On my father's extensive contracts," Mr Brassey asserts, "carried on in almost every country of the civilized world "and in every quarter of the globe, the daily wages of the laborer was "fixed at widely different rates, but it was found to be the almost invari- "able rule that the cost of the work carried out was the same—that for "the same sum of money the same amount of work was everywhere per- "formed"

The *ipsissima verba* have been purposely quoted, for this is a startling statement which can only be accepted in its broad sense Exceptions will arise to prove the rule But Mr Brassey proceeds to clothe the bare announcement with all the reality of ascertained facts When the North Devon Railway was begun, the wage of the laborers was 2 shillings a day During the progress of the work it was raised to 3 shillings Nevertheless the work was executed more cheaply in the latter than in the former period In carrying out a part of the Metropolitan Drainage in Oxford Street, the wages of the bricklayers gradually rose from 6 to 10 shillings a day, yet the brickwork was constructed at a cheaper rate per cubic yard after the wages of the workmen had been raised During the construction of the Refreshment Room at Basingstoke, on one side of the station, a London bricklayer was employed on 5*s*. 6*d* a day, and on the other, two country bricklayers each at 3*s* 6*d* It was found by measurement, made without the knowledge of the men employed, that the *one* London bricklayer laid without undue exertion more bricks than his *two* less skillful country fellow laborers

In 1837 the condition of the inhabitants of the Western part of Ireland was deplorable Their food consisted of potatoes without meal or milk. The cabins were wretched hovels, the beds were of straw, and

the laborers wages were only 6*d* a day. The usual results followed. Poverty and misery deprived them of all energy. Agriculture was at its lowest. The produce of the soil per acre was only one-half the average in England, whilst the number of laborers employed on the same area in Ireland and England was as 5 to 2. During the construction of the Paris and Rouen Railway, there were at one time 500 Englishmen in the village of Rolleboise, most of whom were employed in the adjacent tunnel. Although these English navvies earned 5 shillings a day, while the Frenchmen employed received only half a crown, yet two adjacent cuttings under precisely similar circumstances cost less per cubic yard with the English navvies than with the French laborers. The mileage cost of the Delhi and Amritsar Railway has been found to be about the same as a similar line in England, although the daily wages on the Delhi line were marvellously low. Earthwork is executed by the coolies at a cheaper rate than in England, but native skilled labor is more expensive.

"The execution of the works on a railway in India," says Mr Brassey, "is generally undertaken by small contractors or middle men, who in many cases are shopkeepers. There is a difficulty in obtaining experienced sub contractors, and, in consequence, it is necessary to employ a numerous body of English foremen. Hence the cost of supervision is greatly enhanced in India, and is found to amount on the average to 20 per cent on the entire outlay. Before the railways caused an increased demand for labor, wages ranged from 4*d* to 4½*d* a day. The demand for labor raised wages considerably, but even then the coolies were not paid more than 6*d* a day. However, these wages far more than sufficed to supply all their wants. Their food consists of 2 lbs of rice a day mixed with a little curry, and the cost of living on this their usual diet is only 1*s* a week. For 1*s* 6*d* they can live in comparative luxury. On the railways of India, it has been found that the great increase of pay which has taken place has neither augmented the rapidity of execution nor added to the comfort of the laborer. The Hindoo workman knows no other want than his daily portion of rice, and the torrid climate renders watertight habitations and ample clothing alike unnecessary. The laborer, therefore, desists from work as soon as he has provided for the necessities of the day. Higher pay adds nothing to his comforts, it serves but to diminish his ordinary industry.*

After a review of work done in France, Italy, Austria, Switzerland, Spain, Germany, Belgium and Holland, Mr Brassey makes this remarkable statement:—"The wages paid in England are higher than in any "other country. Yet even with respect to bridges, viaducts, tunnels,

* "It is not," says McCulloch, "in the best situated countries or those of which the climate is the finest and the soil most productive, that the peasantry are the best off. In those their necessities are few and easily supplied, and when they are satisfied they seem to care for nothing more. Humboldt tells us that it had been proposed to prohibit the culture of the banana in Mexico as being the only means calculated to rouse the torpid qualities of the natives and make them in some degree industrious.—page 95

"and all works of art on railways, they can be executed at a cheaper rate "in England than in any other country in the world. The rate of wages "is much lower but masonry costs as much in Italy as in Manchester."

To those who have to employ *convict labor* it will be interesting to learn that the Prussian Councillor of State, Jacobi, is considered to have proved that in Russia, where everything is cheap, the labor of the serf is doubly as expensive as that of the laborer in England. In Austria the labor of a serf is one-third that of a free hired laborer. Slave labor was once employed on the Drainage Works at Rio Janeiro. But free Portuguese labor even at 4*s.* 6*d.* a day was infinitely cheaper. 80 slaves on an estate in Pernambuco produce 171½ tons of sugar. Their annual cost of maintenance and replacement was £765. Their first cost was £4,050, interest on which at 12 per cent. was £486. This gives a total of £1,251, which was expended in producing 171½ tons of sugar, at £7 3 per ton. The wage of the free negro laborer without food was 10¾*d.* per diem. Allowing that the number of free laborers equalled that of the slaves, though it was generally admitted they worked harder, the total cost would amount to £1,080 or £6 3 per ton. The free native laborer is thus but little above the level of the slave. His work is more effective by only one day in the week, and it proved cheaper to engage the European laborer at five times the rate of wages than to employ slaves.

The miserable pay of the *women employed* in the manufactories of Russia suggests to Mr. Brassey some observations on the evils which necessarily arise from subjecting the female population to excessive manual labor. These may be quoted as possessing great interest to Indian Engineers.

"In all the less civilized countries of Europe the women are compelled to share in the manual labors of the men. This practice is in a large degree the cause of that very poverty which it is intended to alleviate. The introduction of so many additional hands into the labor market has a marked effect in diminishing the reward of labor. In Russia on the Lemberg and Czernowitz line half the people employed were women. They earned 1 60 francs a day, and the men from 2 to 3 francs. On the Bukovina line the wages of the men for picking were 1*s.* 6*d.* a day, while the women, who worked only with the shovel, earned about 6*d.* a day less than the men. The cost of living for a man, his wife, and three children in Hungary, may be stated approximately at 1*s.* a day. In those countries the cost of unskilled labor is small, but the struggle for life is so severe, that every child the moment it can add the smallest fraction to the earnings of the family is sent into the fields. The infant mortality in Russia is appalling. The peasant women give birth to their offspring under circumstances equally perilous to the life of both. Their confinement takes place in a

barn or a stable They have no medical attendance, and in three days they are once more employed in hard field labor The result of such privation and suffering is, that a large proportion of infants die within a week after their birth The number of males living at the age of 5 years in proportion to the total number of the population is 20¾ per cent less in Russia than in Great Britain, France and Belgium The shortness of the average duration of life is equally lamentable In the North West Provinces, the average limit of life is between 22 and 27 In the Volga Basin and South Eastern Provinces it is 20 years In Viatka, Perm and Orenburgh it is only 15 years

IV Hours of Labor —We have seen that the mere rate of daily wages affords no indication of the cost of the work Mr Brassey shows that it is equally true that the hours of labor are no criterion of the amount of work performed The Messieurs Dollfus of Mulhausen reduced the daily working hours of their Establishment from 12 to 11, and promised the men that no reduction would be made in their wages if they performed the same quantity of work After a month's trial the men did in 11 hours not only as much work, but 5 per cent more than they had previously performed in 12 Miners work 12 hours a day in South Wales, and only 7 in the North of England, yet the cost of getting coals in Aberdare is 25 per cent more than in Northumberland In Messrs. Ransome and Sim's at Ipswich 1,200 artizans are employed In 1872 their hours of work were reduced from 58½ to 54 per week but so strenuously did the men labor, that the power required to work the tools was actually increased by 15 per cent "The leisure which the "wealthy enjoy," says Mr Brassey, "is their highest privilege The "want of opportunity for thought and cultivation is the greatest privation "of those who are compelled to pass the greater part of their lives in "manual or mental toil" The eloquent language of M Jules Simon in his essay on labor will doubtless be fully appreciated by the generally overworked Indian official "Cette condition paraît assez dure Ce n'est pas à cause du travail, dont personne ne se plaint, ni à cause de la privation du superflu, c'est parce que dans une vie ainsi faite il ne reste pas de place pour l'étude, pour la possession de soi-même Ce besoin d'étudier et de penser n'existe pas partout, même en France Il faut pour l'éprouver une certaine élevation de sentiment, autrefois rare, aujourd'hui presque universelle, au moins dans les grands centres de population A quoi tient ce changement? Au progrès général, aux merveilles scientifiques accomplies chaque jour sous les yeux de la foule, à l'augmentation de bien-être résultant de l'augmentation du nombre des produits manufacturés, à une instruction plus étendue et plus repandue, à l'orgueil légitime inspire par

les souvenirs de la Révolution et par la possession des droits politiques"

V *Wages, their rise and fluctuations*—In the Engineering Trade in England there has been no appreciable augmentation since 1852 in the wages earned by the operatives even in recent years The following Table (page 193) was obtained from the Canada Works at Birkenhead They were established in 1854 The average number of hands is 600

"In England," says Mr Brassey, and it is an observation well worthy of note by us in India, "wages would have risen to a far higher scale, unless the enlightened policy of free trade had been adopted, *and improved communications by sea and land* had given increased facilities for the importation of cattle and other supplies from distant countries" The following Table (page 194) of the prices of provisions in the rural districts of Staffordshire will show how much has been accomplished by the liberal fiscal policy of England in reducing the cost of the necessaries of life

The well known builders, Messrs Lucas and Brothers, state that for some years prior to September 1853, the rate of wages was as follows —

	For Mechanics, Masons, Bricklayers, Carpenters and Plasterers	Laborers
Previous to 1853,	5*s* per day of 10 hours	3*s* per day of 10 hours
From September 1853 to March 1861,	5*s* 6*d* per day of 10 hours	3*s* 4*d* per day of 10 hours
March 1861 to Sept 1865,	7*d* per hour, or 5*s* 10*d* per day	4¼*d* per hour, or 3*s* 6½*d* per day
Sept 1865 to May 1866,	7½*d* per hour, or 6*s* 3*d* per day	4½*d* per hour, or 3*s* 9*d* per day
May 1866 to present time,	8*d* per hour, or 6*s* 8*d* per day	4¾*d* per hour, or 3*s* 11½*d* per day

They consider that the price of building has increased 30 per cent between 1853 and 1872 Turning to other countries, we find that in France Belgium and Germany, the three chief competing countries with England, the prices of food and consequently of labor are 30 per cent dearer than they were 20 years ago. In France 20 years ago laborers were content to work for 1*s* 6*d* a day, now 2*s*. 4*d* is the ordinary rate of pay In the famous establishment for building Engines at Creusot 10,000 persons are now employed, and the annual expenditure in wages is £400,000. Mechanics were paid when the establishment was first created 2½ francs a day, now none receive less than 5 francs Between 1850 and 1866 the mean rate of advance was 38 per cent At the great Zinc Works,

Table of Average Rates of Wages paid to skilled workmen at the Canada Works, Birkenhead

	1854	1855	1856	1857	1858	1859	1860	1861	1862	1863	1864	1865	1866	1867	1868	1869
	s d	*s d*	*s d*	*s d*	*s d*	*s d*	*s d*	*s d*	*s d*	*s d*	*s d*	*s d*	*s d*	*s d*	*s d*	*s d*
Fitters,	29 0	28 3	29 0	30 6	28 10	27 6	27 6	27 0	27 10	28 0	28 0	28 1	31 0	32 6	31 0	30 0
Turners,	29 4	30 3	31 3	33 0	31 6	31 0	32 0	31 6	32 0	31 6	31 6	31 5	31 6	31 0	30 0	29 4
Copper Smiths and Braziers,	31 6	30 10	28 10	29 0	28 0	30 0	31 0	29 6	28 6	28 1	31 6	31 7	32 6	32 0	32 0	30 9
Grinders,	27 0	27 0	27 0	24 0	24 0	22 0	26 0	25 6	27 0	27 6	27 6	32 0	28 6	32 0	26 6	23 0
Smiths,	31 0	34 0	32 0	31 0	30 0	29 6	30 3	30 0	29 6	31 0	30 6	30 3	31 9	32 9	31 6	30 0
Boiler Smiths,	34 0	34 0	35 0	34 0	32 6	33 0	33 8	33 0	32 6	33 0	33 0	34 6	36 0	37 0	36 0	36 0
Bricklayers,	34 0	31 5	34 0	34 0	34 0	34 0	34 0	34 0	34 0	34 0	34 0	34 0	34 0	34 0	34 0	34 0
Saddlers and Belt makers,	26 0	27 0	26 0	26 0	27 0	26 0	27 0	27 0	27 0	27 0	27 0	25 6	24 0	24 0	25 0	26 0
Forgemen,	36 6	37 0	36 0	33 6			33 0	36 0	35 6	35 0	34 6	33 0	32 9	33 0	32 6	32 6
Painters,	24 0	23 0	24 0	26 0	26 6	25 0	27 0	26 0	25 6	25 6	25 8	26 6	27 6	24 6	24 0	23 0
Moulders,	32 0	31 6	33 0	33 0	32 0	31 6	31 6	32 6	32 0	32 6	35 0	33 0	32 9	34 6	34 2	31 6
Joiners and Pattern makers,	28 0	28 6	29 0	28 2	27 6	29 0	29 6	30 0	29 6	29 6	29 0	30 0	30 6	31 4	30 9	30 0
Boiler makers,	31 6	31 0	30 6	32 6	30 0	30 6	31 0	31 6	31 0	31 6	31 3	31 9	34 2	33 0	32 0	32 0

Table of prices of Provisions (Retail) extracted from the Books of Mr George Dix, Grocer and General Dealer, May 26th, 1869

	1849	1850	1851	1852	1853	1854	1855	1856	1857	1858
	£ s d	£ s d	£ s d	£ s d	£ s d	£ s d	£ s d	£ s d	£ s d	£ s d
Flour, per sack,	1 11 6	1 7 0	1 8 0	1 10 0	1 15 6	2 2 6	2 5 0	2 2 6	1 18 6	1 10 6
Cheese, per lb,	0 0 6½	0 0 6½	0 0 6½	0 0 6	0 0 6½	0 0 7	0 0 7	0 0 8	0 0 9	0 0 8
Butter ,,	0 1 2	0 1 3	0 1 1	0 1 2	0 1 2	0 1 4	0 1 4	0 1 4	0 1 4	0 1 4
Bacon ,,	0 0 8	0 0 7½	0 0 8	0 0 7½	0 0 8	0 0 7	0 0 8	0 0 8½	0 0 9	0 0 8
Tea ,,	0 5 0	0 5 0	0 5 0	0 5 0	0 5 0	0 5 0	0 5 0	0 5 0	0 5 0	0 4 8
Coffee ,, ..	0 1 6	0 1 6	0 1 4	0 1 4	0 1 4	0 1 4	0 1 4	0 1 4	0 1 4	0 1 4
Sugar ,,	0 0 5¼	0 0 5¼	0 0 5	0 0 5	0 0 5	0 0 5	0 0 5	0 0 5	0 0 6½	0 0 6
Candles ,,	0 0 6	0 0 5¾	0 0 5¾	0 0 5	0 0 6¼	0 0 7½	0 0 7¾	0 0 7¼	0 0 7½	0 0 7
Soap ,,	0 0 5¼	0 0 6	0 0 5¼	0 0 5¼	0 0 5	0 0 5	0 0 5	0 0 4½	0 0 4½	0 0 4½
Beef ,,	0 0 7	0 0 6	0 0 6	0 0 6	0 0 7	0 0 7	0 0 7½	0 0 7½	0 0 7½	0 0 7½
Mutton ,,	0 0 6¼	0 0 6	0 0 6	0 0 6	0 0 7	0 0 7	0 0 7½	0 0 7½	0 0 7½	0 0 7
Bread ,, ..	0 0 1½	0 0 1⅛	0 0 1¼	0 0 1¼	0 0 1½	0 0 2⅜	0 0 2¼	0 0 2⅛	0 0 1⅝	0 0 1¼

	1859	1860	1861	1862	1863	1864	1865	1866	1867	1868	1869
	£ s d	£ s d	£ s d	£ s d	£ s d	£ s d	£ s d	£ s d	£ s d	£ s d	£ s d
Flour, per sack,	1 9 6	1 14 0	1 16 6	1 16 0	1 10 0	1 8 0	1 10 0	1 14 6	2 0 6	2 3 0	2 15 0
Cheese, per lb,	0 0 7¼	0 0 8¼	0 0 8¼	0 0 7½	0 0 7[illegible]	0 0 8	0 0 8½	0 0 10	0 0 9	0 0 7½	0 0 8¼
Butter ,,	0 1 4	0 1 4	0 1 4	0 1 3	0 1 3	0 1 4	0 1 5	0 1 6	0 1 3½	0 1 6	0 1 6
Bacon ,,	0 0 8	0 0 8½	0 0 9	0 0 8	0 0 8	0 0 8	0 0 9	0 0 9	0 0 8	0 0 8¼	0 0 10
Tea ,,	0 4 6	0 4 6	0 4 6	0 4 0	0 4 0	0 3 8	0 3 8	0 3 8	0 3 6	0 3 6	0 3 6
Coffee ,, ..	0 1 4	0 1 4	0 1 4	0 1 4	0 1 4	0 1 4	0 1 4	0 1 4	0 1 4	0 1 4	0 1 4
Sugar ,,	0 0 5¼	0 0 5½	0 0 5½	0 0 5¼	0 0 5	0 0 5	0 0 5	0 0 5	0 0 4½	0 0 4½	0 0 4¼
Candles ,,	0 0 7	0 0 7¼	0 0 7¼	0 0 6½	0 0 6	0 0 6¼	0 0 6	0 0 6¼	0 0 6¼	0 0 6¼	0 0 4¼
Soap ,,	0 0 4½	0 0 4½	0 0 4½	0 0 4½	0 0 4½	0 0 4½	0 0 4½	0 0 4½	0 0 4½	0 0 4½	0 0 4½
Beef ,,	0 0 7	0 0 7½	0 0 7½	0 0 8	0 0 7½	0 0 7½	0 0 8¼	0 0 8	0 0 7½	0 0 7½	0 0 8¼
Mutton ,,	0 0 7½	0 0 7½	0 0 7½	0 0 7½	0 0 7½	0 0 8	0 0 8	0 0 8½	0 0 7½	0 0 7	0 0 9
Bread ,, ..	0 0 1¼	0 0 1⅜	0 0 1½	0 0 1⅜	0 0 1¼	0 0 1⅛	0 0 1¼	0 0 1⅜	0 0 2	0 0 2⅛	0 0 1

known as the Vielle Montagne near Liege, where 6,500 hands are employed, wages have increased 45 per cent in 12 years In Italy since 1861 wages have risen in some trades 50 per cent In Sicily and in lower Silesia the pay of the working classes has doubled since 1860

VI The industrial capabilities of different nations compared —This is an extremely interesting subject, but our space does not admit of our enlarging upon it We will merely record of few general facts, and insert a rather long quotation relating to India At the locomotive building works in *Belgium,* the parts of the engines made from the same pattern are seldom interchangeable but this is always the case in England In all works in sheet iron the Belgians excel but in wrought-iron they are behind many other countries A good lock and key is no where to be found A tolerable horse shoe is no where to be seen And yet in carriage building they have been eminently successful The capabilities of *Englishmen* are conspicuously shown in their superior skill as miners Mining is perhaps the most exhausting and laborious of all occupations. It has been found that in this description of work the English miner surpasses the foreigner all over the world. In point of manual skill, the *French* and *English* are considered equal In invention the Frenchman may be the cleverer of the two but in the power of throwing energy into his labor, the Englishman is the better man If a Frenchman has a good model of a machine he will make it as well as an English mechanic, but the same number of English workmen will turn out four machines when an equal number of Frenchman will make only one Great pains were taken on the Paris and Rouen Railways to ascertain the relative industrial capacity of the Englishman and Frenchman and it was found to be in the ratio of 5 to 3 But as carpenters the French are superior to the English, both in the quality of their work, and in the price at which they do it "In original conception," says Mr Brassey, "*English manufacturers* do not perhaps possess any advantage over the manufacturers of other countries, but in the practical development and application of an invention, and in general administrative capacity, and especially in the art of economical management, they have shown a real commercial genius, which is rarely exhibited abroad " But in many continental markets the English no longer enjoy the advantages which they formerly possessed Foreign manufacturers, with their cheaper labor and more intimate knowledge of the character and requirements of the people, are rapidly gaining ground English *iron* masters compete with difficulty with the iron

works at Cologne, which supply many of the Russian Railways with *bridges* In *tyres* we have to a great extent been driven out by Krupp Of the large quantities of *files* now used in Russia, two-thirds come from Germany English *saws* on the contrary meet with an increasing sale, their price having been reduced by one-half within the last few years Imitations of English *lathes* are made in Germany for half the price, and are largely imported into Russia

In connection with Indian Railways the following information supplied by Mr Brassey may be quoted at length —

"The experience of the Consulting Engineers of our Indian Railways does not by any means go to prove that foreign iron masters or engine builders can successfully compete with the English Their experience, it may be added, is all the more valuable, because the Indian Railways afford the most perfect example of a purely neutral market There is no personal influence acting on the minds of Indian Railway Engineers and Directors prejudicially to our interests, and no customs duties, which are protective to our manufacturers, are imposed upon the importation of our manufacture into India The plant and machinery for the Indian Railways are purchased in the cheapest markets, and it is certain that the foreigner would be preferred regardless of national sympathies, if he could compete with the iron trade at home, either in quality or price Let us then examine into the actual state of the facts, as regards the supply of rails and locomotives to the Indian Railways

"I shall first appeal to the experience of Mr A M Rendel In November and December 1865, tenders were invited by advertisement for a large number of locomotives for the East Indian Railway Eminent foreign as well as English makers were free to compete, and 22 tenders were sent in The result was, that 80 engines, varying in cost from £3,165 to £2,150, were ordered from English makers, at an average price of £2,600 each, 20 from Kiessler, of Esslingen, near Stuttgart, at £2,550 each, and 20 from an English maker, at £2,440, so that the foreign maker received a price intended to be intermediate between those of the English makers It ought to be mentioned that at the date when the order was given, English houses were full of work Not long afterwards, in consequence of the rapid development of traffic on the East Indian Railway, it became a matter of urgent importance to send out additional locomotives as early as possible Accordingly 10 more engines were ordered from an English firm at the price agreed upon in the first tender, viz, £2,450, and 10 more were ordered from Esscher Weiss and Co of Zurich, who undertook to make them for £2,550 each, the price which had been previously accepted by the other foreign makers At the termination, however, of their contract, Esscher Weiss and Co, made a representation to Mr Rendel that they had sustained a loss, and asked to be allowed, by way of compensation, to make 10 more engines of the same kind, but at the enhanced price of £2,800 It is, therefore, evident that in the results of their competition with the English makers, who were under no pressure in regard to price, all the shops being so full of work that early delivery was an impossibility, Esscher Weiss and Co had little cause for satisfaction Indeed, they admitted a substantial loss But even if this contract had been more satisfactory to Esscher Weiss and Co, than it actually proved, their success

would have been largely due to British industry, seeing that the boiler plates, the copper fire boxes, the wheels, the pig iron for the cylinders, the tubes, and the frame plates (in short, two-thirds of the materials used in the construction of their engines,) came from England in a manufactured state It was the same with the engines supplied by Kiessler That firm assured Mr Rendel that they could not think of asking him to accept Prussian iron or copper, and that by far the greater portion of their material came from England Of course, to a certain extent, this was done under the requirements of the specification, but no pressure was needed on the part of the engineers The axles and the wheel tyres were specified to be of Prussian steel, but for this, they too would have been of English make But the experience of Mr Rendel is by no means limited to the purchase of locomotives Rails and iron bridge work upon the largest scale have been supplied in England for the Indian Railways for which he has acted, and the tenders have been obtained on all occasions, when a large order has been given, by open advertisement, and all continental makers have been as free to tender and would be accepted on the same guarantees as English makers Yet out of the total expenditure during the last ten years, of from £7,000,000 to £8,000,000 sterling on materials and plant for the East Indian Railways constructed under Mr Rendel's supervision, with the exceptions I have made, the whole of these contracts have been obtained by English manufacturers

Another interesting and conclusive proof of the success with which our engine builders can compete for the supply of locomotives, is furnished by the following schedule, prepared by Mr W P Andrew, of the tenders for 94 locomotives received by the Punjab Railway Company, in answer to a public advertisement in January, 1866

Tenders for supply of Engines for the Punjab Railway

Country from which tender received		Prices per engine and tender £
1	Germany,	3,156
2	England,	2,990
3	England,	2,960
4	England,	2,950
5	England,	2,850
6	England,	2,835
7	England,	2,810
8	England,	2,790
9	England,	2,750
10	Germany,	2,750
11	England,	2,685
12	Germany,	2,680
13	England,	2,680
14	Switzerland,	2,650
15	England,	2,650
16	England,	2,600
17	France,	2,595
18	England,	2,575
19	England,	2,500
20	Scotland,	2,424
21	Scotland,	2,395

The following extract from the "Times" is also interesting under this head —

"*English and American Working Men.*—In pursuance of instructions, United States Consuls in Europe have been supplying to their Government some information relating to the laboring classes, and the chief of the Bureau of Statistics has published the results of the inquiry. The *New York Times* says —"The general conclusion to be drawn from the answers is unfavourable to the efficiency of English labor as compared with American. It would seem that nine hours of an American's labor are equal to about ten of an Englishman's, the superiority being nearly represented by the ratio of 10 per cent. The Consuls at Bradford, Sheffield, and other manufacturing cities and the chief of the Bureau himself, come to this conclusion after much investigation. This is especially true of heavy manufacturing work, such as machine or engineering work and the fabrication of hardware, cutlery, and other manufactures of iron and steel. In all these branches, 900 Americans are thought to be equal to 1,000 Englishmen in the amount of work per week they will accomplish. This corresponds with the experience of our own manufacturers. It has before been observed here that in labors demanding enormous physical strength and endurance—like iron puddling—the Americans were superior to the English, while in patient, steady drudgery, the British 'navvy' or Irish day labourer is much beyond the Yankee, and Mr Brassey's experience is no doubt true, that the English day labourer is the cheapest labourer in the world, because he accomplishes the most for the money. The American demands a toil with some peculiar stimulus to call out his best power. Thus in a dangerous and difficult employment like lumbering, demanding great strength and presence of mind, no nationality is equal to the American. The superiority, however, of which we have spoken, seems to be less true in other branches, and in cotton and woollen manufacture the British superiority is expressed by the ratios of 8 and 6 per cent. The explanation given by the report of the greater efficiency of American labor is probably the true one—that it lies in its greater 'adaptability' owing to the superior education and intelligence of the American factory workman, and in the more temperate American social habits. The English workman requires a day or two to get over his Saturday night and Sunday drinking sprees. The extent to which the English laboring class drink up their wages appears in a melancholy form in this report. The Consul at Sheffield reports that great numbers of working men stop work on Saturday noon, and do not commence again till the following Wednesday. This is, in part because they need Monday and Tuesday to enable them to recover from the effects of Sunday's drinking. 'Increase of pay,' says the Consul at Birmingham, 'means increase of drink.' In Manchester, our Consul reports that many sober working women complained that increased wages and shortened hours of labor were a curse to the families, as the men were only the more tempted to drink. In Liverpool there seems a wide spread and fearful demoralization of the laboring class from their intemperate habits. And thus from almost all the manufacturing centres, our officials report a wretched condition of working men's families and reduced efficiency of labor from the habits of intemperance prevalent. A curious fact also appears in these researches—namely, that a rise of wages does not always produce more work. Thus in the collieries of Leeds the product for each person in 1864 was 327½ tons for 313 working days, or 21½ cwt. for each person per diem. In 1868 it fell to 317 tons, or 20 cwt. per diem, in 1873 to 17½ cwt. for each person per diem. That is a reduction of production in ten years of 19 per cent, while wages

have risen 30 per cent and upward In Manchester, the average earnings of a certain mine were 4s 7d per day in 1871, in 1872 the wages had more than doubled, and yet the earnings were 2d less per week for each man The workmen averaged less than four working days per week, while many only worked three days The statistical proof presented by the United States Bureau of Statistics of the terrible loss and degradation to the English labouring classes produced by their drinking habits, will not be one of the least of the good results accomplished by this able report"

VII Piece Work—Mr Brassey obviously views this subject from an European point of view We will first note what he says, and then see how far it is applicable to the very different conditions which obtain in India "It has always been the aim," says Mr Brassey, "of experi-"enced employers to give to the workman a direct interest in doing his "work with skill and intelligence Slave labor in which the motive "of self-interest is wholly wanting, is, on that very ground as unsat-"isfactory in an economical sense, as it is repugnant to our moral sen-"timents" Adam Smith remarks —"The person who can acquire no "property can have no other interest but to eat as much and labor as little "as possible In ancient Italy, how much the cultivation of corn dege-"nerated, and how unprofitable it became to the master when it fell under "the management of slaves, is remarked both by Pliny and Columella" The late Mr Brassey always looked on day work as a losing game He preferred putting a price upon the work This system was modified to suit the habits of the people with whom he dealt For example, the Piedmontese were paid by the barrow load, a minute measurement peculiar to their country When the railway between Leicester and Hitchin was begun, the piece work system was abandoned, and the men were paid a daily wage of 2s 3d each The excavation then cost 1s 6d per cubic yard. Subsequently the system was changed and piece work introduced, when it cost only 7d The workmen sometimes themselves object to the piece work system, saying, that when executed on equitable terms it is a good thing in itself, but that the small contractor always wants to increase his profits by lessening the prices paid to the working people This objection is one peculiarly applicable to India But we hardly ever experience the next exception It is said, that it makes men overtask themselves, contract intemperate habits, and thus prematurely ruin their constitutions The slaves employed as coffee carriers in the Brazils remove bags of even three hundred weight on their heads a distance of 400 yards They are the most powerful slaves in the Colony, and are paid in proportion to the work performed They work with the most intense vigour, in

order to earn as soon as possible a sufficient sum wherewith to purchase their freedom, and generally succeed in accumulating the amount in four years But they are a short lived race In their devouring anxiety to accomplish their object, they too often sacrifice their health by over exertion, although they are well fed We may here again quote Adam Smith, who says, "The man who works so moderately as to be able to work "constantly not only preserves his health the longest, but in the course of "the year executes the greatest quantity of work"

Some years ago, all Government Engineers in India were strongly urged to introduce in almost every case the contract system But it was pushed too far Failures warned us that the nature and training of the people of this country was not such as to allow the attempt to succeed Indian Contract Work is seldom if ever so well done as work carried out by the usual Departmental Agency It appeared at first to relieve the officers in charge of much labor But it was soon found that this relief was dearly purchased, and that the work of contractors required as much, if not more, supervision than that carried out by daily paid agency The best plan seems to be to employ daily paid workmen, and to periodically check by measurement the cost of the work done In almost every case constant supervision is needed Piece work can of course in such simple matters as breaking stone and digging earth be readily introduced but even here vigilance is needed In everything that can be counted measured or weighed true economy demands that the judgment should be made according to number size and weight The question of quality often still remains and can be only gauged by inspection In England, bricklayers are paid by the number of bricks they lay such a practice with natives would not insure even safe work, unless the supervision was very close We have in India to meet an ever-pressing and never ceasing desire on the part of nearly all with whom we deal to deceive An open and trusting nature is invariably "*done*" Two illustrations may be here recorded. The foundations of a certain building under construction by contract were inspected by an Executive Engineer He found them too shallow, and ordered their deepening to be done while he remained near the spot On this being completed he directed their filling in with masonry to be proceeded with and rode away The moment his back was turned the contractor refilled the trenches with earth, watered and tamped them, and then ran up the masonry above The work had not proceeded far, when, cracks appearing, the trick was found out On another occasion, an

Executive Engineer was inspecting the excavation for foundations of a work which had been correctly lined out by himself, when he found that the lines of two large rooms had been altered so as to shorten each room by a foot or two. He relined these end walls, ordered them to be correctly re-excavated and rode away. The Contractor did not alter the excavation, but stepped out the foundations course by course until the correct internal dimensions of the room were obtained, so that the walls merely rested on the natural ground. Subsequent failures of these walls led to the discovery of the fraud. Similar deceptions might be multiplied *ad libitum*. Possibly education and practice may, in course of time, produce better results. "When an agricultural laborer begins to work on a railway," says Mr Brassey, "he will lie down at 3 o'clock in the afternoon fa- "tigued and incapable of continuing his work, but after an interval of 12 "months with more constant muscular exertion, receiving higher wages, "and having better food, he will get into better condition, and will be able "to perform his task without difficulty." Will a similar improvement ever reach the Natives of India? Have any signs of it yet been seen? Their genius does not lie in Engineering. Engineers see the worst sides of their character. They thus form but poor conceptions of the value of the live material with which they have to work. A distinguished Bengal Engineer, it is true, gives them the following character:—"If they are not "very truthful, are indolent, and sometimes troublesome or even exaspe- "rating, it is no light thing that they are singularly temperate, wonderfully "patient and good tempered, very susceptible to kind treatment and good "management, and that strikes, drunken brawls and grumbling discontent "are simply unknown." A late Bombay Municipal Engineer writes very differently. He says, "It is almost impossible in India to get what we "in England would consider even ordinarily good work. You may have "heard of the Barracks which were condemned the other day. It is the "same on railway works and everywhere throughout India. The Natives "will not give you good mortar, or if you provide mortar they will not "make good work. Masonry in India is at best bad." The experience of our readers will doubtless alternate between these two extremes, and they may perhaps be disposed to say in justification of the Indian Public Works Department generally

. . . A thirst so keen
Is ever urging on the vast machine
Of sleepless labor, 'mid whose dizzy wheels
The power least prized is that which thinks and feels.

September 1875. J. L. L. M.

No CXCIII

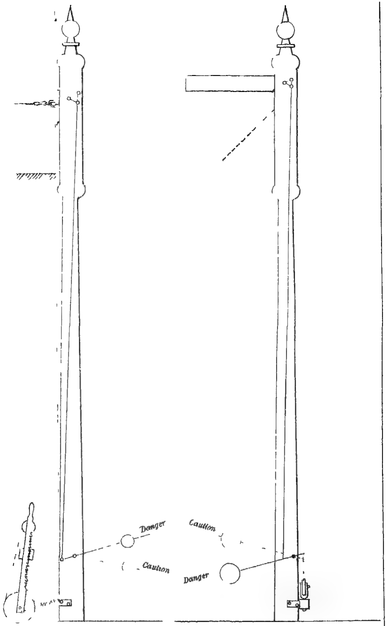
SPENCER'S PATENT COMPENSATOR FOR DISTANT SIGNAL WIRES

[*Vide* Plate XXIII]

Description of an Invention for Compensating the Expansion and Contraction of the Wire Rope of Distant Signals of Railways. By (the late) C. I Spencer, Esq., M I C E

Jubbulpore, 1875

Every Railway Engineer must have felt the difficulty and inconvenience caused by the expansion and contraction of the half mile or so of wire rope which connects the distant signal with the hand lever It is only necessary to watch the operation of working the distant signal to be satisfied that a remedy of some kind is needed The signalman pulls down the hand lever without any visible result on the signal arm He then locks the chain, raises the lever arm again, tightens the expansion rack, and again exerts all his strength at the lever, and after one or two such operations, he finally succeeds in getting in the slack of the wire and dropping the signal arm, to raise it again, he lets go the lever with a jerk, and frequently bends or breaks it, and after he has tried this plan in vain, he walks some way along the wire and plucks at it and shakes it, and is at last rewarded by seeing the signal arm resume the horizontal A common practice of signalmen is to tighten up the rack in the heat of the day, and leave it thus all night, when the contraction is very likely to pull the signal partly down or to snap the wire, and thus disable the signal entirely Again, the counterpoise at the signal-post has to perform the same operation reversed, which has cost the signalman so much labor, *i e*, pull back the whole half mile of wire to its original position, for



eversed

Hand Lev *ck reduced*
pansio *and acting*
(the Rack no *nal Arm*
Compe

Signal post with Counterpoise as in ordinary use (Stevens' Patent)

NOTE —*The Counterpoise weight is often supplemented with broken chairs, it has to lift the Signal Arm, and draw back the whole length of wire*

this the ordinary weights supplied with the signals are insufficient, and it is common to see them supplemented with broken chains, thus increasing the pull at the other end, and the tendency to break the wire

If the wire works round a curve, instead of on a straight line, all the above evils are intensified

Spencer's Compensator provides a simple remedy for the above difficulties The accompanying Plate explains its working and construction

The arrangement of the counterpoise at foot of signal-post is altered, so as to allow the arm to drop by releasing the wire, and *vice versâ* The Compensator being fixed, as shown, in the centre of the wire rope, the hand lever is pulled, and lifts the Compensator weight through a certain height, releasing by so much the second half of the wire, and allowing the signal arm to fall to the position of caution The hand lever is let go, the Compensator weight falls, pulling the second half of the rope and raising the arm to danger

In case of contraction or expansion, the weight rises or falls, keeping both halves of the wire uniformly tense

This invention has been tried experimentally at a large station, for six months in temperatures varying from frosty nights to the hottest days of May, and on a wire rope 933 yards long, stretched over broken ground In all this time the expansion rack has remained a fixture, and the whole arrangement has worked smoothly and easily without once requiring repair

The advantages of the Compensator are—

1*st* Compensation of contraction and expansion, uniform tension and doing away entirely with the use of expansion rack and adjustment by the signalman

2*ndly* The possibility of deflecting the wire at any angle vertical or horizontal at the Compensator without any increase of friction, thus giving facilities for getting round curves or obstacles or over uneven ground, for this purpose, the wheels of the Compensator are placed at any angle to each other, or either half of the wire may approach the Compensator in an upward or downward direction—*see* below

Horizontal deflection—Plan Vertical deflection—Elevation

3*rdly* The practical reduction of friction The pull on the hand lever

is equal to the friction of half the rope, plus a certain weight, and is found in practice to be a much more manageable resistance than the friction of the whole rope At the signal-post, the pull to be overcome by the counterpoise is only equal to the friction of half the rope, or in practice much less than half the friction of the whole rope, *so that the second half of the wire is especially secured from danger of breakage* The constant tension gets the wire into good form, and pulls out the bends and kinks caused by leaving it slack

4thly All the signal gear in present use may continue to be used with the Compensator with slight modification All that is necessary is, to reverse the position of the counterpoise lever at foot of signal-post, as shown in the Plate, and to spike the expansion rack permanently in one position on the hand lever, with this further advantage, that if your patent hand lever breaks, a piece of common plate bar will do to replace it, omitting the expansion rack altogether

The Compensator itself is easy to make A pair of small grooved wheels fixed on to one inch axles and turning true with the axles on iron bushings are required with chains and weights, the weight itself varies in amount according to length of lead and other circumstances, for the above-mentioned lead of 933 yards with several deviations, both horizontal and vertical, a weight of 300 lbs. was found necessary An ordinary straight lead of 800 yards works very well with about 260 lbs If any great excess over these is found necessary in similar circumstances, it is an indication of undue friction in some part of the signal gear, which should be sought out and remedied, it is, however, no advantage to work with the smallest possible weight, a margin ought to be allowed to overcome occasional or accidental friction

The above invention is patented for India, and parties wishing to use the same, are requested to apply to Messrs Burn & Co, Calcuta, from whom also working parts of the machinery may be obtained

The use of bell cranks or levers instead of wheels, may in some cases be preferable, and is included in the patent

C I S

No CXCIV.

FALLS ON THE SUKKUR CANAL

[*Vide* Plates XXIV, XXV, XXVI]

BY LIEUT.-COL. J LEMESURIER, R E

Karachi, 16th February, 1876

THE Plates show the falls which were constructed in 1871-72 on the Sukkur Canal

This canal was opened in 1871, and the experience gained during the first inundation showed plainly that the mouth at the head of the pass would not answer when the river was in flood After the canal had been open about two months, there was a deposit of 11 feet of pure sand at the head, tapering down gradually to a depth of about 2 feet at the 4th mile It became necessary therefore to open a new mouth at once, and the spot chosen was close to the village of Rahuja about four miles above Sukkur There was here an old channel of the river, locally termed a *dhandh*, and though it had silted up somewhat, the supply it drew from the river was sufficient, and could be depended on down to a certain height on the river gauge at Sukkur A new mouth had been commenced here about two years before the canal was opened, but when a portion of the excavation had been completed, the work was suspended, as it was decided that the original mouth should be first tried

The new mouth was commenced with a bottom width of 16 feet, and side slopes of 1 to 1 The surface slope was 1 foot $10\frac{1}{2}$ inches a mile, and to enable the channel to stand the high velocity due to this slope, it was intended that the bed and slopes of the canal should be faced with rough stone pitching

When the time came however for completing the work, it was decided that a preferable plan would be to limit the hydraulic slope to 6 inches a mile, and to meet the difference by the construction of vertical falls near the junction with the old portion of the canal. The site chosen for the falls was about 400 feet above the junction, as the new mouth here cut through a spur of limestone rock.

From the head regulator to the falls, about $1\frac{1}{2}$ miles, the new mouth has a bottom width of 60 feet, and side slopes of 1 to 1. The depth of water required to give the full supply, with a fall of 6 inches a mile, is 9 feet. The mean velocity is 2·27 feet per second, and the discharge 1,432 cubic feet. Below the falls the bottom width of the mouth is 31·25 feet, with side slopes of 1 to 1, and the depth of water is 13 feet. The difference of level between the beds above and below the falls in 7·55 feet, and of the water lines 3·55 feet.

The plan of the falls is shown in *Plate* XXIV. The crest of the masonry portion of the weir is 9 inches above the bed, and it is divided into five bays of 11 feet each by piers 4 feet thick. The thickness of the weir is 2 feet 6 inches: it is in fact nothing more than a brickwork facing to the rock, forming an even surface against which the gates can slide. The design of the masonry of the falls requires no particular description, as there is no cistern or basin, and the lower retaining walls are simply continuations of the abutments. The bed and banks of the mouth below the falls, as far as the junction with the canal, a distance of about 400 feet on a curve, are protected with rough stone pitching, laid dry, about 1 foot 6 inches or 2 feet thick.

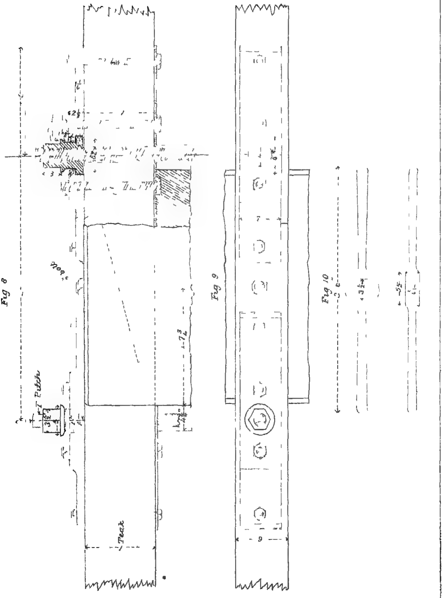
The plan of using sliding gates to form the weir, instead of building up a mass of masonry above the bed, is, it is believed, entirely new, and as it has answered so well at the Sukkur canal for four seasons, a description of it may not be uninteresting.

The gate is constructed of 4-inch teak plank with a strip of $3\frac{1}{2}$-inch angle-iron along the top and bottom of the down-stream face. The gate is strengthened at front and back by four strips of $\frac{3}{8}$-inch plate iron 4 inches wide, and by two cross pieces of $3\frac{1}{2}$-inch angle-iron at the back, as shown in *Fig* 7, *Plate* XXV. The gate, when lowered to the full extent, rests on a piece of teak $11' 8\frac{1}{2}'' \times 5'' \times 4\frac{1}{4}''$, fastened to the brickwork by bolts, and its top is then level with the crest of the masonry, or 9 inches above the bed of the canal. It slides up and down against two vertical

FALLS ON THE SUKKUR CANAL

(Enlarged Drawings of Gates)

Scale 1/12 d feet = 1 inch



straining pieces of teak, scantling $5'' \times 4\frac{1}{2}''$, fastened by lewis bolts to the piers, which are recessed for the purpose, the thickness of the pier being 4 feet, and of the upper cutwater 3 feet $3\frac{1}{2}$ inches

When the full supply is going over the gate, its top is 5 feet above the level of the bed, or its bottom 9 inches below the crest of the masonry The man in charge of the falls has orders to keep the gauges at the head regulator and at the falls reading the same, and when this is the case, the surface slope of the water is 6 inches per mile If less than 9 feet is admitted at the head, the gates at the falls are lowered until the two gauges read the same If at any time it is necessary to admit a greater depth than 9 feet, the gates are raised

The apparatus for raising or lowering the gates is very simple Across the cutwaters a teak beam, 9 inches wide by 12 inches deep is laid, and bolted down to the piers by a 2-inch bolt The screws which are attached to the gates are of 2-inch rod cut to $\frac{1}{4}$-inch pitch they pass through holes cut in the teak beams, and are wound up and down by a brass nut, which turns between two iron plates bolted to the beams as shown in *Fig* 8, *Plate* XXVI The brass nut is 7 inches deep, the lower 4 inches being circular, with a collar $1\frac{1}{4}'' \times 1\frac{1}{2}''$, and the upper 3 inches hexagonal $3\frac{1}{2}$ inches across The nut is turned by the iron handle, shown in *Fig* 10, *Plate* XXVI, two of which are required for each gate

It would be easy, of course, to have bevelled wheels to turn both the screws of each gate at once, but this would add to the expense, and as long as the two men are careful that they make simultaneous half turns of the handles, the gates are not found to jam As the gates are very quickly raised or lowered, and they never have to be shifted much at one time, one pair of handles is found to be sufficient for the whole of them, and this requires two men for the establishment for looking after the falls

In the cold weather, when the mouth is dry, the wood and ironwork of the gates is well dressed with common fish oil, procured from the fishermen on the river

The gates are 11 feet 8 inches long, and as the opening in which they slide is 11 feet $8\frac{1}{2}$ inches, they have a play of $\frac{1}{4}$-inch at each end There is also a small play between the front of the gate and the back of the masonry of the weir wall $\frac{1}{4}$-inch is shown in the Plate, but it is in reality less than this The 4-inch strips of plate iron are countersunk into the front of the gate, but not into the back, and all the rivets and bolts as

well, so that the face of the gate is perfectly level and flush, and there is no reason why more than $\frac{1}{16}$-inch play should be given It was considered advisable, however, as the gates had to be made in Karachi and sent up to Sukkur ready to be put up, to allow for $\frac{1}{4}$-inch play when building the masonry

One advantage of this kind of fall, and a very great one, is that it suits a variable depth in the canal, as the gate can be raised or lowered according to the depth of water admitted Another advantage appears to be, that the action of the water upon the bed and banks below the fall is reduced to a minimum The canal is merely protected by a comparatively thin layer of rough stones procured from the excavation and laid dry, and up to the present time no repairs of any sort have been required The bed and banks of the canal above the falls are almost as clean as the day they were cut, as whatever the depth of water is, the surface slope is kept fixed at 6 inches a mile, and the mean velocity never exceeds $2\frac{1}{4}$ feet per second

J LeM

No CXCV

THE LIMIT OF ELASTICITY.

Remarks on MAJOR C A GOODFELLOW'S "*Notes on the Position of the Neutral Axis in a Beam subjected to Transverse Strain*"* BY J C DOUGLAS, ESQ, *East India Govt Telegraph Department, Soc. Telegraph Engineers, &c, &c*

THE term "limit of elasticity" or "elastic limit" was adopted when knowledge of the phenomena of resistance of materials was far less complete than it is at present, and when in fact the received theoretical ideas in respect to the relation between elasticity and *set* were erroneous The more complete knowledge of the phenomena and consequent correction of the theory do not necessarily imply departure from established practice, the facts obtained by experience remain equally facts under the new theory, but the theoretical explanation of the facts being different, the nomenclature applicable under the erroneous theory requires such modification as will render it proper to convey the new ideas This is necessary to avoid confusion, or the retention of theoretical ideas proved erroneous It has become necessary either to adopt some other term "in lieu of limit of elasticity," or to clearly recognize that the term no longer applies to that idea it was originally selected to convey, and therefore requires a new definition

It was presumed that within a certain limit, materials were perfectly elastic and no set resulted from the application of a load less than the proof load, but the assumption of such a strictly defineable limit is at

* No CLXX, Professional Papers on Indian Engineering, [Second Series]

variance with what is known of other physical properties of matter, it based on imperfect data, and therefore never strictly defined It w length proved that a set resulted from the application of a load far than the proof load, the experiments of Fairbairn and Hodgkinson p this conclusively, but the inference that every load, however small, w produces a permanent set when first applied, must necessarily cause ture if applied continuously or repeatedly, appears to have been assumption as erroneous as the previous one of a limit of elasticity S an inference leads to a contradiction, for it is known that materials dc in practice fail under such relatively small loads, e g, iron will recei set under a load far below what it is usually loaded with in practice, practice is justified by experience, and an engineer is not condemne rash for adopting four as a factor of safety with a material which is kr to receive a set with a load only one-tenth of the ultimate load If hypothesis be corrected by an appeal to experiment and observation, found contradicted by observation, and by the experiments of Lloyc successive breakages of the same bar, and by Kirkaldy s experiments A a careful examination of all the modern works on the subject which c be found in the British Museum Library, and the Bibliothèque Natior Paris in 1847, the following conclusions were adopted as expressing present state of knowledge of this subject

"It was supposed that no set was produced by loads within the l of elasticity, but it is now known that loads well within this limit do ca a set, and it is highly probable that every load, however small, caus set on its first application, the set in the case of a relatively small being inappreciable The set due to the action of a load within the lim elasticity, is not increased by repeated applications of the load, and, a having received such a set, the material is more perfectly elastic for lo not exceeding that which produced the set If a load exceed the limi elasticity of the material, repeated applications of the same load ca an increasing set, until the material is either fractured or fails by be distorted so much as to become useless The limit of elasticity or of p fect elasticity, the elastic strength or the proof strength, of a piec material, is now more correctly defined as the greatest stress it will b without injury —i.e, the greatest stress which does not produce an incre ing set on repeated application" (Manual of Telegraph Construct page 31)

Unfortunately the term limit of elasticity is frequently used without being defined, and sometimes the obsolete definition is given and the student is confused by the evident contradiction It will be seen that the above definition does not necessarily raise factors of safety formerly adopted , it may act the other way, for the hasty conclusion that a permanent set necessarily implied ultimate fracture, may in some cases have led to the use of factors of safety unnecessarily high

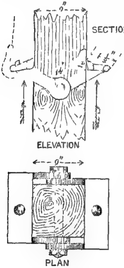
J C D

[*Note by Editor* —Statements substantially the same as the above will be found in Arts 87 and 88 of Part I of the Roorkee College Manual of Applied Mechanics, 1873, by Capt A Cunningham, R E]

No CXCVI

CLAWS FOR PILE DRAWING

THE contrivance here shown was found useful for drawing the main piles of the Cofferdams at Apollo Bunder in Bombay Its only advantage over other means of attachment is, that it grasps the pile without damaging it, so firmly, that there is no risk of slipping or breakage unless the wood be fairly torn asunder



The piles were 9 inches square, and the bolt holes for the upper tier of waling pieces $1\frac{1}{2}$ inches diameter, so the bolt upon which the two claws hinge, was made of the same diameter to fit the same hole

The power is applied by means of two of "Weston's Differential Blocks" suspended from above, or two 10-ton screw jacks resting on pieces of wood, which are loosely clamped on either side of the pile, through which the pressure is transmitted directly to the ground The claws are made so, that when the power is applied for drawing the pile, the compressive force exerted at the two lips is equal to the force exerted at the bolt hole which tends to split the pile, and would in many instances do so if this tendency were not counteracted

Those piles which have already been drawn by this method were driven from 10 feet to 15 feet below the ground surface, through strata of soft mud, stiff clay, and gravel into a bed of hard moorum, and the power required to draw them varied as nearly as can be calculated from 5 tons to 10 tons according to circumstances, yet in no instance where the claws were used, were the edges of the piles damaged

The most advantageous way of working is to draw the pile from four to six feet with the differential blocks or screw jacks, and then hoist it the rest of the way by a jib crane, light tackle, or other means at hand

No. CXCVII.

SPECIFICATIONS FOR ROOF COVERINGS

[*Vide* Plates XXVII to XXXII]

Extracted from the Schedule of Specifications and Rates for the use of the 4th Circle, Military Works BY J. P. C ANDERSON, ESQ, *Assoc Inst. C E, Supdg Engineer.*

[The following specifications are based on the experience of many years and in many different parts of the Punjab, and embrace the details of the latest practice in the several descriptions of work detailed below Although prepared for use in the 4th Circle of Military Works, in the stations of Umballa, Jullundur, Ferozepore, Mooltan, Dagshai, Kasauli, &c, they will be found applicable to most stations in Northern India, and useful to Engineers throughout the country]

Allahabad Tiling.—

(*a*) —Single tiling consists of one set of flat tiles laid on battens, with their vertical junctions covered with a layer of semi cylindrical tiles, all the tiles are to be set dry

(*b*) —Double tiling consists of a set of flat tiles laid on battens with their vertical junctions covered with a layer of semi hexagonal tiles, over which is placed a layer of flat tiles with their vertical junctions covered with semi cylindrical tiles, all the tiles are to be set dry

(*c*) —All tiles are to be made of thoroughly well tempered clay, they are not to be dressed or shaped till they are sufficiently dry to prevent their getting out of shape, and are not to be put into the kiln till they are thoroughly dry In moulding the tiles, the greatest precaution is to be taken that the moulds furnished to the men making the tiles are accurate, and that similar moulds are perfectly true in their sizes

(*d*) —When the manufacture of tiles is in progress, all the moulds must be examined and measured by the Executive Engineer or an Assistant Engineer every 10 days, to see that they have not got out of shape

(*e*) —The tiles are to be thoroughly burnt and sound without flaws, well shaped with sharp square edges, and to have a good metal ring

(*f*) —All buttons, swellings, and projections, are to be formed solid in the mould, and not attached to the tile after it is moulded

(*g*) —The size and shape of each separate description of tiles are to be precisely similar

(*h*) —The following points are to be carefully attended to in laying the tiles —

1 The battens on which the first layer of pan tiles rest, must be of one uniform scantlings with their sides cut square, they are to be placed parallel to each other at central distances of 1 foot, and with their upper surfaces in one plane

2 The two ridge battens are to be put on first at the required distances from the apex of the roof to suit single or double tiling as the case may be, and the remainder at the proper intervals down to the eaves, the length of the eaves being regulated so that the roof shall terminate with a whole tile and be not less than 15 inches in breadth

3. All tiles must lock freely and properly into each other, so as to set perfectly one on the other, and form an even upper surface

(*i*) —The upper layer of pan tiles are to be placed immediately over the lower layer, with their sides resting on the semi-hexagonal tile, and the semi-cylindrical tiles resting over the semi hexagonal tiles

(*k*) —Whenever it is necessary to make tiles for hips, valleys, &c, &c, they should be cut with a saw to the required angle before the tiles are burnt

(*l*) —Any tiles that are cracked, chipped, underburnt, or damaged in any way, must not be put into the roof

(*m*) —The tiles must be laid in accurate regular lines, so that a string held at the middle of the outer plane of the semi hexagonal or semi cylindrical tiles at the apex of the roof and at the eaves, shall pass over the centres of all semi-hexagonal and semi-cylindrical tiles in that line

At all angles and exposed points where the roof is liable to be lifted by the force of storms, the wall plates are to be bolted down with ¾-inch round iron bolts, from 2 to 3 feet in length buried into the masonry, the end of these bolts in the masonry are to have broad heads to prevent the bolt being drawn out

Corrugated Galvanized Sheet Iron —

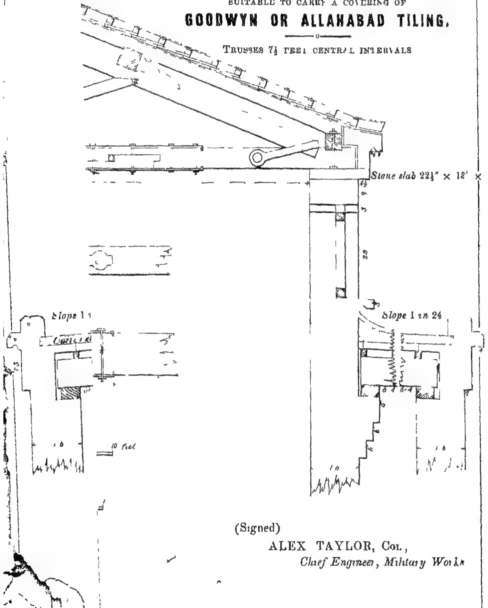
(*a*) —As it has been found that kelo (or *Cedrus deodara*) corrodes zinc when the two are brought into contact To prevent injury to the galvanizing of the corrugated iron, battens of chil (or *Pinus longifolia*) are invariably to be used for the iron to rest on, where however kelo wood rafters exist, strips of chil wood are to be nailed down over them before the corrugated iron is laid on

(*b*) —The success of corrugated iron as a roof covering depends to a great extent on the rivetting The holes for the rivets should always be made in the ridges not in the furrows of the sheet, when in position they should, in the first instance, be punched with a fine thin pointed *punch*, to mark the points, and the bit then cut out clean with a full sized punch, and punching block. In marking the points for the rivets, any two sheets to be connected together are to be placed with what will be the lower surface uppermost, and one over the other in their proper positions, with a 6 inch lap for the horizontal joints, and in

FIG 1
FIG 2

DETAILS
OF A
ROOF OF FIR OR DEODAR TIMBER,
OF 24 FEET SPAN,
SUITABLE TO CARRY A COVERING OF
GOODWYN OR ALLAHABAD TILING.

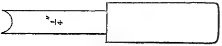
TRUSSES 7½ FEET CENTRAL INTERVALS



(Signed)
ALEX TAYLOR, Col.,
Chief Engineer, Military Works

the vertical joints with one corrugation lap, for a 5 inch wide corrugation, and two corrugation lap, for any corrugation less than 5 inches in width, and the fine pointed thin punch driven through **both** sheets. The sheets are then to be placed, with what will be their lower surfaces uppermost, and the full sized bolt holes cut out clean.

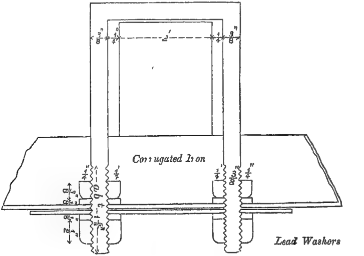
Section of Punch



(c) —In fixing the rivets, the sheets are to be placed in position on trestles 18 inches high, and the rivets passed through from below, and held up with the rivet heads on an iron bar resting on a block of wood placed on the ground, a galvanized iron washer is then put on, and the bolt rivetted with a light hammer, and finished off with a cupping tool placed on the rivet, and the head beaten out.

(d) —When the sheets of iron have thus been connected, they are to be secured to battens of the proper dimensions, placed at central distances of half the lengths of each rivetted sheet, with $\frac{3}{8}$ inch round or $\frac{1}{4}$ inch square cramps, as shown below, with a play of $\frac{1}{4}$-inch between the cramps and the batten, to allow

Cramp for fixing iron on Roof,
$\frac{1}{2}$ full size



for contraction and expansion. These cramps are to be fixed at every second batten, and their longitudinal distances apart are to be the width of the exposed portions of the sheets.

(e) —Wind bars of wrought-iron, $1\frac{1}{8}'' \times \frac{1}{4}''$, 1 inch angle iron, or $\frac{1}{2}$-inch round-iron, are to run the whole length of the roof, at three batten space intervals, commencing from the eaves batten, and secured with iron cramps, as described above.

(*f*) —The eaves sheeting is to consist of $\frac{1}{16}$ inch galvanized sheet iron, 1 foot wide, cut into shapes

At all angles and exposed points where the roof is liable to be lifted by the force of storms, the wall plates are to be bolted down with $\frac{3}{4}$-inch round iron bolts from 2 to 3 feet in length, buried into the masonry, the ends of these bolts in the masonry are to have broad heads to prevent the bolt being drawn out

(*g*) —The connections at the gables, at chimney, or air shafts, or other projecting masonry, to be rendered water-tight by the introduction of 20 B W G galvanized iron flashing, in the case of gables 18 inches wide and the length of the sheets used in the roof covering, and in the case of chimney or air shafts 2 feet broad and the entire length of the shaft

In the case of chimney or air shafts coming through the slope of the roof, a cross gable roof is to be made, 1 foot wider (6 inches on either side) than the shafts, to prevent the rush of water from the roof coming against the shafts

Mud —

(*a*) —To consist of good clay, 4 inches deep, damped, well beaten down, clay, plastered and leeped, laid on 4 inch diameter rolls of sirkandá (reed) resting on one layer of perfectly well burnt stock-moulded 1st class tiles, 12″ × 6″ × 1″ soaked for three hours under water, and laid with their sides drawn up with mortar

(*b*) —To consist of good clay, 4 inches deep, damped, and well beaten down, either on brushwood placed on matting on sirki, or sirkandá (reed) resting on rafters or battens at 1 foot central intervals, the upper surface to be mud plastered and leeped

Oil Cloth —

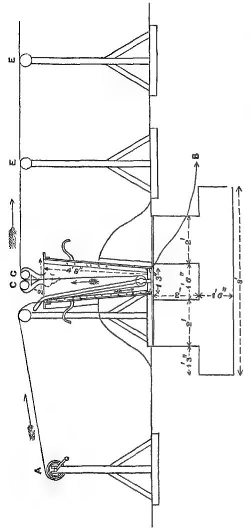
(*a*) —The cloth to be used is to be the double warp cloth from the Cawnpore Mills, and is to be soaked in a composition made of 15 lbs pure linseed oil, 5 lbs finely pounded litharge, and one part pure bees wax, all boiled together

(*b*) —Great care must be taken to ensure the use of none but pure linseed oil, as the success of the cloth being made waterproof depends mainly on the use of pure linseed oil, which is the only oil which dries properly, and if mixed with other oils it loses this property

(*c*) —Five maunds of pure linseed oil are to be placed in an iron caldron 2 feet broad at the top, 1 foot broad at bottom, 4 feet high and 5 feet long, and boiled over a charcoal fire for about five hours, or till small bubbles rise on the surface, the litharge finely pounded is then to be added, the whole well mixed and the boiling continued for another two hours, the mass being stirred every quarter of an hour, after this, the bees wax is to be added, when the wax melts, the whole composition is to be well stirred, when it will be ready for use So soon as the composition is ready for use, the fire is to be lessened and only sufficient kept up to keep the mass in a liquid state

(*d*) —Each piece of cloth is about 46 inches wide and 46 feet in length; in coating it with oil one end is to be drawn out and passed (*see* sketch on page 217) under the roller B at the bottom of the caldron, then carried between two guides CC, it is then to be drawn over a series of rollers EE, and finally wound round a drum on which it remains till used The object of the guides CC, is to remove all

surplus composition from the cloth, and return it into the caldron instead of losing it during the passage of the cloth over the rollers, the guides should consequently be placed sufficiently close together to remove the surplus composition



To avoid the difficulty of getting the cloth under roller A, the second piece to be coated with oil should be tacked to the end of the first piece before the latter is drawn through the oil, and is to be detached when the head of the second piece is well outside the caldron

(*e*) —The strips of prepared cloth are to run across the roof, and not longitudinally

(*f*) —Before placing prepared cloth as a covering over shingled roofs, the edges of shingles at the ends are to be rounded off, to prevent the sharp edges injuring the cloth The cloth is then to be rolled off either on the ground or placed in position and secured at the top, and is to be kept in that position till it shrinks, it is then to be made to pass down the steps of the shingles, and is not to be stretched tight, and it is to be tacked down with tin tacks ¾ inch long with broad heads

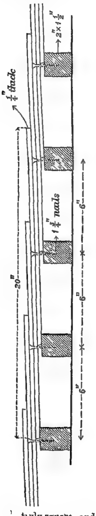
Shingling —

(*a*) —All battens to be dressed to one uniform scantling of 2 inches by 1¾ inches, and secured to the roof timbers placed at central distances of 6 inches and in parallel lines

(*b*) —The shingles to be cut with square edges, and of one exact uniform lengths

of 20 inches, to be laid on battons at 6 inches central intervals in three layers, with the head of the first layer abutting against the fourth batten from the end, and the end of the fourth shingle over lapping 2 inches, the head of the first shingle. The shingles are to be laid on with intervals of $\frac{1}{16}$-inch, and made to break joint. In the dry season the shingles are to be soaked in water in half casks before being put on.

(*c*)—The nails are to be made of $\frac{1}{8}$ inch iron wire, they are to be $2\frac{1}{2}$ inches long with broad heads, and with the ends for a length of only $\frac{1}{4}$ inch beaten out to a point, and they are to be made red hot and dipped in coal tar before they are used.



(*d*)—Each shingle is to be secured by only two nails driven one on either side of the shingle, the first nail is to be in the first shingle and the second nail in the shingle immediately above, this gives one nail per shingle.

At all angles and exposed points where the roof is liable to be lifted by the force of storms, the wall plates are to be bolted down with $\frac{3}{4}$-inch round iron bolts, from 2 to 3 feet in length buried into the masonry, the end of these bolts in the masonry are to have broad heads to prevent the bolt being drawn out.

(*e*)—The connections at the gables, at chimney, or air shafts, or other projecting masonry, to be rendered water-tight by the introduction of 20 B W G galvanized iron flashing, in the case of gables 18 inches wide and the length of the shingles used in the roof covering, and in the case of chimney or air shafts 2 feet broad and the entire length of the shaft.

In the case of chimney or air shafts coming through the slope of the roof, a cross gable roof is to be made, 1 foot wider (6 inches on either side) than the shafts, to prevent rush of water from the roof coming against the shafts.

Slating—

(*a*)—The slates are to be laid either on planking or on battens placed at central distances of one-third the length of the slates less 2 inches, that is, for 20 inch slates, the battens are to be 6 inches central distances, all battens on which slates rest are to be dressed to uniform scantling secured to the roof timbers.

(*b*)—The slates to be used are to be what are technically called Duchesses, 24" × 12", or Countesses, 20" × 10", or such other sizes as may be procurable, not less than 12 inches in length, they are not to exceed $\frac{1}{4}$-inch in thickness, or to be less than $\frac{1}{8}$ inch, are to be sound, with smooth, even surfaces, free from cracks, scales, fissures, or other imperfections, are to be dressed truly square, and are to be gauged to the required dimensions, all slates with broken corners, crooked, or in winding, are to be rejected.

(c).—On battens, the slates are to be laid as described in para (a) above. The heads of slates are to rest ¼-inch on the fourth batten from the end, which will give the fourth slate a lap of 1¼ inches on the first slate, *see* sketch on page 218.

(d).—The slates are to be secured with galvanized iron nails, 1¾ inch long, one per slate, placed on the middle line of the slate, and into the batten immediately below the one on which the head is resting; with a 20 inch slate the nail hole will be 6½ inches from the head.

(e).—The nail holes are on no account to be punched, but must be drilled and countersunk with a bit, having a tapered or bevelled shoulder, so as to receive the swell of the nail head, and prevent it coming in contact with the next upper layer or course of slates.

(f).—Every course of slates is to break joint with the course above and below it—at least 6 inches in the case of Duchesses, and 5 inches in the case of Countesses, *i. e.*, the centre of each slate to occur exactly over the joining of the two slates above and below it.

(g).—Whole slates are to be laid throughout the entire surface of the roof, save at the commencement of the course near the gables, where it may be necessary to break joint.

(h).—The connections at the gables, at chimney, or air shafts, or other projecting masonry, to be rendered water-tight by the introduction of 20 B. W. G. galvanized iron flashing; in the case of gables 18 inches wide and the length of the slates used in the roof covering, and in the case of chimney or air shafts 2 feet broad and the entire length of the shaft.

In the case of chimney or air shafts coming through the slope of the roof, a cross gable roof is to be made, 1 foot wider (6 inches on either side) than the shafts, to prevent rush of water from the roof coming against the shafts.

(i).—Stop flashing to be in sheets of the required sizes, having two thirds slipped in under the bottom of the slates, and one third turned up at right angles next the masonry.

(k).—Top flashing to be 6 or 7 inches wide, having 3 or 4 inches built into the masonry during its construction, and the remaining 3 inches bent down over the turned up portion of the stop flashing.

(l).—The ridge to be secured from leaking by the portion of the ridge pole projecting above the roof being covered with zinc sheeting. The sheets to overlap each other 3 inches, to be bent over the ridge pole (which should project 3 inches above the top of the roof), and to lap at least 6 inches over the top course of slates at each side of the ridge; they are to be prevented from blowing off or buckling up, by straps of hoop iron painted, and bent over the sheets at intervals of 2 feet apart. The whole (including the hoop iron ridge sheeting and wooden ridge piece) to be bolted through.

Tiled and Terraced

(a).—To consist of one layer of flat tiles soaked in thick whitewash set in lime mortar laid over 2½ inches concrete placed on two layers of flat tiles set in lime mortar.

(b).—The lower layers of flat tiles are to be 12" × 6" × 1", laid in two courses over scantlings placed 1 foot central distances apart. The first layer of tiles is to be set with their sides drawn up with mortar, the second layer of tiles to

break joint with the lower one, and to be embedded in mortar, and to have their sides drawn up with mortar

(*c*).—The mortar for the plaster to be composed in the following proportions, all by measure —

1 At Jullundur, 1 part fresh slaked stone lime, 2 parts charcoal burnt fresh slaked finely sifted kunkur lime, and $1\frac{1}{2}$ parts fine sifted surkí of thoroughly well burnt clay

2 At Dalhousie, Dharmsála, Kangra, Kasauli, Dagshai, Subathu, Jutogh, and Umballa, of 2 parts fresh slaked stone lime, and 3 parts fine sifted surkí of thoroughly well burnt clay

3 At Ferozepore, of charcoal burnt fresh slaked finely sifted kunkur lime

4 At Mooltan, of 2 parts fresh slaked stone lime, and 3 parts clean river sand or fine sifted surkí of thoroughly well burnt clay

(*d*).—Great care must be taken to see that the surki is not made of 2nd class bricks or under burnt clay, and that none but clean sand is used

(*e*).—In making the mortar with quick lime, fresh quick lime is to be slaked under water into a paste in a tank, half cask, or bucket, and allowed to stand for a fortnight with the water the whole time 1 foot above the paste, after which the water is to be run off, the proper proportion of surkí added, and the mass worked up in a mortar-mill into a stiff plastic paste It is then to be ground fine in a hand mill

Particular care is to be taken that the mortar is not drowned with water while undergoing hand-mill grinding

(*f*).—The tiles for the layers under the concrete are to be perfectly well burnt stock moulded, well shaped flat tiles, 12″ × 6″ × 1″, and are to be soaked under water for four hours immediately before being used

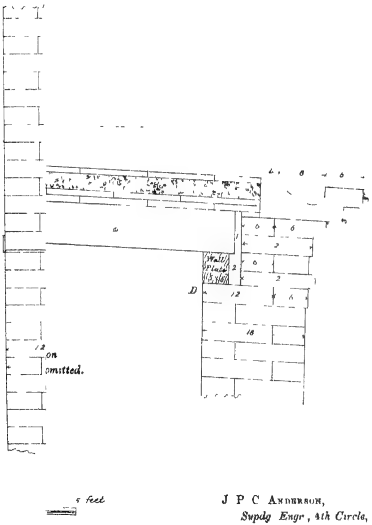
(*g*).—The concrete is to be made in the proportion of 1 part of dry mortar to 3 parts of unburnt kunkur, the siftings of kunkur lime, the siftings of súrki or broken stone in $\frac{1}{2}$-inch cubes all by measure The unburnt kunkur, siftings of súrkí or broken stone must be soaked under water for three hours immediately before being added to the mortar

After the concrete has been spread, it must be wetted and beaten with slight quick strokes with a hand flail, till the mortar is drawn up to the surface, and the mass is well set

(*h*).—Covering the concrete is to be a layer of tiles similar to those described in para (*f*), and soaked in thick whitewash with their sides drawn up with mortar as described above

(*i*).—Over the last layer of tiles is to be spread 4 inches of clay, for six months, to allow of the concrete to set, after which the clay is to be removed

(*k*).—At the junction of a tiled and terraced roof with a wall, a row of tiles 12 inches long is to be set 6 inches into the wall, over this is to be laid another row of tiles breaking joint with the lower one, and let 3 inches into the wall, the lower surface of the first tile is to be 2 inches above—what will be the completed surface of the tiled and terraced roof, and filled up with concrete, after the concrete is finished This is done to prevent the leakage of the roof with its junction with the wall



J P C Anderson,
Supdg Engr, 4th Circle,
Military Works

Thatch

I BAMBOO FRAMES

(a) —The bamboo work of a roof is to consist of rows of single whole bamboos at 3 feet central intervals placed longitudinally, on which, and crossing them, are to be tied rows of single whole bamboos arranged at 9 inch central intervals, running across the roof—that is, from the apex to the eaves, over these, and crossing them, are to be laid bamboos split in halves arranged at 6 inch central intervals, and firmly tied down with bân string The bamboos are to be tied together at all points of their intersection with each other

The bamboo framework is to rest on, and secured to battens at 3 feet central intervals resting on common rafters, or to purlin rafters also at 3 feet central intervals, resting on the principal rafters of a truss

(b) —Newly cut bamboos are not to be used, as they are liable to weevil (gun)

(c) —Repairs of bamboo frame may consist of petty or general repairs The former will always be executed on the roof unless specially ordered to the contrary, in the latter it may be necessary to remove the frame and repair it on the ground This will only be the case with tied frames

(d) —In most cases, when a frame is removed from a roof for repair, it will be economical to break it up and entirely remake it In this case, the serviceable material will be selected The rate to include removing from roof, selecting material, &c

(e) —Where mats are laid over a bamboo framework, they will be laid with their edges overlapping, and tied down by battens of split bamboo, so laid that in no place shall 1 superficial foot of matting be left without its batten

II GRASSING

(a) —The several descriptions of grass roofs are to be well and tightly or closely tied, laid in one, two or three layers, according to circumstances

(b) —The grassing of a roof, if properly executed, should not sink perceptibly with the weight of a man standing on it, nor should the blades of grass be pulled out by the feet of a man walking over it

Where the thickness of grassing is 9 inches when finished, it will be laid on in three layers the first, not exceeding one third of the whole thickness, may be of *surpot* or *khassa*, or other coarse grass, and it may be in the first instance laid loose on the roof and tied tightly down with bamboo battens, not more than 9 inches asunder, with ties at not greater intervals than 9 inches The second and third coats to be always of thatching grass, made up into tatties on the ground, each of thickness sufficient to form one third of the finished coating, the grass is to be closely packed and tied with two bamboo battens below, and two above, and with ties at intervals not greater than 18 inches, each layer of tatties to be separately laid and tightly tied on to the roof, with ties at not greater intervals than 9 inches The whole surface of the finished roof to lie evenly, without rises or hollows

(c) —Where the thickness of grassing is to be 6 inches, or 3 inches, it must be laid on in two layers, or in one layer of thatching grass, laid, as specified above for the upper layers

(d) —The eave bundles are to be of the full thickness of the grass coating, evenly and tightly laid, cut off squarely neatly and perfectly straight

(e) —Where the renewal of a top coat has to be executed, the old top coat will

be entirely removed All hollows will be made up evenly with fresh grass laid under the battens of the lower coat, to which new ties, wherever required, will be given, and the top coat of new grass will then be laid on as above, and new eaves' bundles given of the full thickness of the grass roofing

(*f*) —Petty repairs of grass roofs will consist of new grass passed into the old top coating to cover any bamboos that may have become exposed, or to stop leaks, in renewing ties, where loose or decayed, and in replacing single battens where these have become displaced

(*g*) —In renewing the whole or any portion of a roof, the serviceable grass and bamboos are to be carefully selected and tied in bundles, of size similar to those of new grass

(*h*) —Where a new grass roof or renewal of old grass, or of top coat of grass, has to be executed, the whole of the ridge and hips shall be neatly bound over with sirkí matting, securely tied down over a roll of grass

(*i*) —The following precautions must be strictly attended to in executing thatching —

1 —A piece of ground is to be pointed out by the Executive Engineer, the distance from the nearest thatched building not to exceed 200 yards, here a work-yard will be established, and all straw and materials required for the works will be deposited

2 —The straw will be made up into tatties and bundles at this yard, and will be carried to the building as it is required

3 —In stripping a roof, the grass fit to be used is to be tied in bundles, and immediately removed to the work yards, the refuse grass, as it is collected, is to be carted away at once Towards sunset on each day, if there be any grass remaining near the building, it is to be taken back to the work yard, and all grass, whether new or old, is to be cleared away from near the building before the workpeople are allowed to leave

4 —A chowkeedar must be appointed in charge of the yard, who is to take proper precautions to guard against fire, he must also conform to any rules that may be published by the authorities in cantonments

(*k*) —Rope ladders are to be fixed to the ridge of all thatched roof coverings, and are to lie on the slope of the roof to the eaves The side ropes are to be of closely twisted 5 inch circumference munj rope, and the rings are to be of pieces of bamboo, 2 feet long passed through the strands at 2 feet intervals, and lashed

Allahabad Single and Double Tiling

Stations	Labor						Materials						Total Rate of Work		
	Quantity or Number	Description	Rate	Cost of Labor			Quantity or Number	Description	Rate	Cost of Materials					
				RS	A.	P				RS	A	P	RS	A	P
MOOLTAN	2	Masons,	-/8/-	1	0		110	Flat tiles, (per °/oo,)	37/-/	4	1	1			
	4	Coolies,	-/3/6	0	14	0	110	Halfround tiles (per °/oo,)	36/-/-	3	15	4			
	¼	Head mistree,	-/12/	[illegible]	3	0									
		Carried over,	..	2	1	0		Carried over,		8	0	5			

Stations	Quantity or Number	LABOR Description	Rate	Cost of Labor RS	A	P	Quantity or Number	MATERIALS Description	Rate	Cost of Materials RS	A	P	Total Rate of Work RS	A	P
MOOLTAN—(*Continued*)		Brought over,		2	1	0		Brought over,		8	0	5			
	¼	Bheesty,	-/4/-	0	1	0	3	Ridge caps, (per %)	37/ /-	0	1	9			
		Profit to Contractor,		0	8	0	3	Ventilating tiles, (per %)	56/ /	0	2	8			
							10 r f	Concrete filling, (per %)	10/-/	1	0	0			
		Total cost of labor per 100 s ft,		2	10	0		Total cost of materials per 100 s ft,		9	4	10			
								Total cost of single tiled roofing, per 100 s ft,					11	4	10
								Total cost of double tiled roofing, per 100 s ft,					23	14	10

Country Tiling on 6" Thatch

Stations	Quantity or Number	Description	Rate	RS	A	P	Quantity or Number	Description	Rate	RS	A	P	RS	A	P
FEROZEPORE		Grammy,	-/4/-	0	4	0	100 sft	6" thatch, as per detail,	6/2/	6	2	0			
	1	Coolie,	-/2/-	0	2	0	500	Tiles,	3/ /-	1	8	0			
	⅛	Bheesty,	/4/	0	0	6									
		Total cost of labor per 100 s ft,		0	6	6		Total cost of materials per 100 s ft,		7	10	0			
								Total cost of 100 s ft roofing,					8	0	6

Country Tiles, on Matting

Stations	Quantity or Number	Description	Rate	RS	A	P	Quantity or Number	Description	Rate	RS	A	P	RS	A	P
JULLUNDUR	2	Grammies,	-/4/-	0	8	0	1,000	Tiles,	2/8/	2	8	0			
	2	Coolies,	-/2/-	0	4	0	4srs	String, (per maund,)	2/8/	0	4	0			
	⅛	Bheesty,	-/4/-	0	0	6	48	Bamboos,	3/2/	1	8	0			
		Profit to Contractor,		0	4	0	100sf	Matting,	/10/	0	10	0			
		Total cost of labor per 100 s. ft,		1	0	6		Total cost of materials per 100 s ft,		4	14	0			
								Total cost of 100 s ft. roofing,					5	14	6

Corrugated Galvanized Iron Sheeting

Stations	Labor: Quantity or Number	Labor: Description	Labor: Rate	Cost of Labor: RS	A	P	Materials: Quantity or Number	Materials: Description	Materials: Rate	Cost of Materials: RS	A	P	Total Rate of Work: RS	A	P
KASAULI	4	Smiths rivetting,	-/6/-	1	8	0	180 lbs	= Weight of 100 s ft iron							
	4	Coolies ,,	-/3/-	0	12	0	48 lbs	= $\frac{4}{15}$ added for laps							
	2	Smiths fixing,	/6/-	0	12	0	——								
	2	Coolies ,,	/3/-	0	6	0									
	1	Carpenter,	-/6/-	0	6	0	728 lbs	Cwt qr lbs = 2 0 1 at per cent,	20/-/-	40	7	2			
	¼	Head mistree,	/12/-	0	3	0		Carriage of do,	7/-/-	14	4	0			
		Ropes, scaffolding, &c,		0	4	0	4 lbs	Rivets, iron,	/6/-	1	8	0			
		Profit to Contractor,		0	4	0	2½ lbs	Washers, iron,	/6/-	0	15	0			
							8	Clips and nuts,	/5/-	2	8	0			
							2 lbs	Lead washers,	-6/6	0	13	0			
							3 lbs	White lead,	/4/-	0	12	0			
							½	Bottle oil,	/12/-	0	6	0			
							20 lbs	= 10′ × 2″ × $\frac{5}{16}$″ wind ties,	-/4/	5	0	0			
							4 lbs	= 4 bolts, $\frac{5}{8}$″ diameter,	-/4/-	1	0	0			
		Total cost of labor per 100 s ft,		4	7	0		Total cost of materials per 100 s ft,		67	9	2			
								Total cost of 100 s ft roofing,					72	0	2

Mud on Reeds and Tiles

Stations	Labor: Quantity or Number	Labor: Description	Labor: Rate	Cost of Labor: RS	A	P	Materials: Quantity or Number	Materials: Description	Materials: Rate	Cost of Materials: RS	A	P	Total Rate of Work: RS	A	P
MOOLTAN	1	Mason, . .	-/8/-	0	8	0	200	Tiles, 12″ × 6″ × 1¼″,	8/8/-	1	13	11			
	6	Coolies,	/3/6	1	5	0									
	1	Bheesty,	-/4/6	0	4	6	1 c f	Lime,	60/-	0	9	7			
	2½ cf	Grinding mortar,	2/ /-	0	0	9	1½ c f	Surkí,	12/8	0	9	0			
							100 s f	Sirkandá rolls,	4/8/-	4	8	0			
		Profit to Contractor,		0	8	0	100 s f	Grass matting,	-/6/-	0	6	0			
							33 c f	Mud mortar, plastered and leeped,	5/8/	1	13	0			
		Total cost of labor per 100 s ft,		2	10	3		Total cost of materials per 100 s ft,	.	9	7	6			
								Total cost of 100s ft roofing,	.	..	.	.	12	1	9

Mud on Reeds and Matting

Stations	Labor: Quantity or Number	Labor: Description	Labor: Rate	Cost of Labor: RS	A	P	Materials: Quantity or Number	Materials: Description	Materials: Rate	Cost of Materials: RS	A	P	Total Rate of Work: RS	A	P
MOOLTAN	½	Mason,	-/8/-	0	4	0	100 s.f	Sukandá matting,	2/ /-	2	0	0			
	4	Coolies,	-/3/6	0	14	0	100 s f	Sukanda rolls,	4/8/-	4	8	0			
	1	Bheesty,	-/4/6	0	4	6	100 s f	Grass matting	/8/	0	8	0			
		Profit to Contractor,		0	8	0	33 c.f	Mud beaten & plastered,	5/8/-	1	13	0			
		Total cost of labor per 100 s ft,		1	14	6		Total cost of materials per 100 s ft,		8	13	0			
								Total cost of 100 s ft roofing,					10	11	6

Shingling

Stations	Labor: Quantity or Number	Labor: Description	Labor: Rate	Cost of Labor: RS	A	P	Materials: Quantity or Number	Materials: Description	Materials: Rate	Cost of Materials: RS	A	P	Total Rate of Work: RS	A	P
JUTOGH	4	Carpenters squaring and dressing shingles,	-/7/-	1	12	0	750	Shingles,	25/ /-	18	12	0			
							7½ lbs	Nails, 2¾" long, at 100 to a lb,	-/4/-	1	14	0			
							10 srs	Charcoal,	1/4/	0	5	0			
	4	Carpenters for putting shingles on roofs,	-/7/-	1	12	0	4	Bags of water,	-/ /6	0	2	0			
								Tar, ropes, &c,		0	8	0			
								Ridging,		1	12	0			
	7	Coolies,	-/3/-	1	5	0									
	½	Smith,	-/8/-	0	4	0									
	½	Coolie attending smith,	-/3/	0	1	6									
	¼	Head mistree,	/12/-	0	3	0									
		Profit to Contractor,		0	10	6									
		Total cost of labor per 100 s ft,	..	6	0	0		Total cost of materials per 100 s ft,		23	5	0			
								Total cost of 100 s ft roofing,	..				29	5	0

Slating

Stations	Labor: Quantity or Number	Labor: Description	Labor: Rate	Cost of Labor: RS	A	P	Materials: Quantity or Number	Materials: Description	Materials: Rate	Cost of Materials: RS.	A	P	Total Rate of Work: RS	A	P
UMBALLA	5	Dressing slaters,	/6/	1	14	0	220	Slates 24" × 12', per 100,	15/8/-	34	1	7			
	3	Coolies,	/2/6	0	7	6	220	Nails, zinc,	-/4/-	0	12	9			
	¼	Head mistree,	/12/	0	3	0		Ropes, baskets, &c.,		0	2	0			
	220	Boring holes,	/4/	0	8	9									
		Profit to Contractor,		0	8	0									
		Total cost of labor per 100 s. ft.,	•	3	9	3		Total cost of materials per 100 s. ft.,		35	0	4			
								Total cost of 100 s. ft. roofing,	•				38	9	7

Tiled and Terraced

Stations	Labor: Quantity or Number	Labor: Description	Labor: Rate	Cost of Labor: RS	A	P	Materials: Quantity or Number	Materials: Description	Materials: Rate	Cost of Materials: RS.	A	P	Total Rate of Work: RS	A	P
JULLUNDUR	3	Masons setting tiles,	/6/	1	2	0	550	Flat tiles, 12" × 6" × 3	8/8/	4	10	9			
	3	Coolies,	/2/6	0	7	6	21 c f	Concrete,	29/2/-	6	1	10			
	⅓	Bheesty,	/4/-	0	2	0	2 22 cf	White lime,	47/2/	1	0	9			
	¼	Head mistree,	/12/	0	3	0	4 44 cf	Kunkur lime,	84/2/	1	8	3			
	10 c f	Grinding mortar,	2 -/-	0	3	2	3 34 cf	Surki,	11/2/-	0	6	7			
		Hods, baskets, &c.,		0	4	0	250 sf	Whitewash,	-/1/6	0	3	9			
		Profit to Contractor,		0	8	0	33 cf	Mud beaten down,	-/8/-	0	2	9			
							33 cf	Taking off mud and spreading about site,	-/4/-	0	1	5			
		Total cost of labor per 100 s. ft.,	•	2	13	8		Total cost of materials per 100 s. ft.,	•	14	4	1			
								Total cost of 100 s. ft. roofing, ..	..	.	.		17	1	9

Thatch, 9", 6" and 3"

Stations	Labor						Materials						Total Rate of Work		
	Quantity or Number	Description	Rate	Cost of Labor RS	A	P	Quantity or Number	Description	Rate	Cost of Materials RS	A	P	RS	A	P
		9" Thatching													
UMBALLA	7	Grammies,	/4/-	1	12	0	900	Bundles of grass,	3/ /-	2	11	0			
	3	Coolies,	/2/	0	6	0	60	Bamboos,	2/ /-	1	3	2			
		Profit to Contractor,		0	6	0	8 srs	String,	2/8/-	0	8	0			
							100sf	Matting	/10,-	0	10	0			
		Total cost of labor per 100 s ft,		2	8	0		Total cost of materials per 100 s ft.,	.	5	0	2			
								Total cost of 100 s ft 9" thatching,					7	8	2
		6" Thatching													
	5	Grammies,	-/4/-	1	4	0	600	Bundles of grass,	3/-/	1	12	8			
	2	Coolies,	-/2/	0	4	0	48	Bamboos,	2/ /	0	15	4			
		Profit to Contractor,		0	4	0	5¼ srs	String,	2/8/	0	5	3			
							100sf	Matting,	/10/-	0	10	0			
		Total cost of labor per 100 s. ft,		1	12	0		Total cost of materials per 100 s ft,		3	11	3			
								Total cost of 100 s ft 6" thatching,					5	7	3
		3" Thatching													
	2	Grammies putting on new,	/4/-	0	8	0	800	Bundles of grass,	3/-/-	0	14	4			
	1	Coolie,	-/2/-	0	2	0	3¾ srs	String,	2/8/-	0	3	9			
	½	Grammie repairing old,	-/4/-	0	2	0	36	Bamboos,	2/ /-	0	11	6			
		Profit to Contractor,		0	2	6	100sf	Matting,	-/10/-	0	10	0			
		Total cost of labor per 100 s ft,		0	14	6		Total cost of materials per 100 s ft.,	.	2	7	7			
		*						Total cost of 100 s ft 3" thatching,	..				3	6	1

Thatch 9", 6" *and* 3"—(Continued)

Stations	LABOR — Quantity or Number	LABOR — Description	LABOR — Rate	Cost of Labor RS	A	P	MATERIALS — Quantity or Number	MATERIALS — Description	MATERIALS — Rate	Cost of Materials RS	A	P	Total Rate of Work RS	A	P
UMBALLA—(*Continued*)		*Note*—The above rates include the following cost of framework and matting, which is to be deducted when they are not given													
	1	Grammy,	/4/-	0	4	0	1¾ srs	String,	2/8/	0	1	9			
							24	Bamboos,	2/ /-	0	4	0			
							100sf	Matting,	/10/	0	10	0			
		Total,		0	4	0		Total,		0	15	9			
								Total amount to be deducted,					1	3	9

J P C A

No CXCVIII

EXPERIMENTS ON STRENGTH OF INDIAN CEMENTS.

Extract from letter from P DEJOUX, ESQ, C E, *Exec. Engineer, Cement Experiments Division*

Dated Sealdah, 6th Feb, 1875

Portland Cement to be manufactured in Calcutta —With reference to orders received requiring a certain quantity of cement for trial on a larger scale, I have been going on (with the present limited means at my disposal) with its manufacture

I had in stock 17 casks, of which three have been sent to the North-Western Provinces, and one to the Exec Engineer, 3rd Calcutta Division

The annexed Statement A shows further results obtained from test of the Portland Cement manufactured by me

It will be seen therefrom, that the late samples Nos 12, 15, 16, 17 and 18 afforded better results than those previously tested

The reason for this change is, that before beginning the experiments on cements, I analysed the water of the tank in my office compound, and as I found it contained a feeble proportion of sulphate of lime, it was used but after the recent heavy rains, I traced a marked decrease in the strength of the cement

This led to a fresh analysis of the water, and the result showed that the proportion of the sulphate of lime had increased very sensibly

The cause for this deviation may be explained by considering that the level of the water having been very low before the last heavy showers, the bottom of the tank got much disturbed by them, and thus a notable quantity of the sulphate of lime contained in the earth got dissolved in the water

The last mixture was therefore made with river water, and the quality of the cement consequently improved very much thereby

This point is worth particular notice in the manufacture of either Portland or Artificial Cement, for which the quality of the water used for mixing raw materials must be carefully tested

Margohi Cement—Of 5,341 cubic feet of this cement manufactured during last year, 3,147 were used on the Sone Weir at Dehree, which, after being submitted to the heavy floods of the last rainy season, afforded very good results, as reported lately by the Exec Engineer of the Dehree Division

The appended Statement B shows further tests of the cement lately manufactured mixed with sand, and it is obvious that the tensile strength of such samples as were made properly is increasing very steadily, and that a very strong mortar can be obtained with this cement

I need not here repeat that it is absolutely necessary to entrust the manufacture of cement of this kind to the direct charge of a competent manager with some chemical knowledge

In fact, the manufacture of every kind of cement requires great care and attention, and the constant test and analysis of raw materials is particularly obligatory, otherwise the consequences result in anything but what is satisfactory

A.

Statement of Experiments made with Michele's Testing Machine, showing the tensile strength of Calcutta Portland Cements.

Numbers	Description	Age	After what time immersed	How long immersed	Weight in lbs supported before breaking on an area of 1½″ × 1½″	Breaking weight per square inch	Quantity of water used in mixing the cement	Remarks
140	Indian Portland Cement No 1,	8½ months	24 hours	8 months 13 days	Does not break at 1,000 lbs.		30 per 100	Mixture made with tank water before rains
348	Ditto Nos 10 and 11,	2½ „	Ditto	2 months 13 days	890 lbs	395¼	Ditto	
368	Ditto Nos 10 and 11 mixed with Nos. 1, 2 and 5,	8 days	Ditto	6 days	370 „	166¼	Ditto	Do do, after the rain.
369	Ditto ditto	9 „	Ditto	Ditto	420 „	186½	Ditto	Ditto ditto
370	Ditto ditto	Ditto	Ditto	Ditto	400 „	177½	Ditto	Ditto ditto
371	Ditto ditto	8 days	Ditto	Ditto	430 „	191	Ditto	Ditto ditto
372	Ditto ditto	Ditto	Ditto	Ditto	360 „	160	Ditto	Ditto ditto
373	Ditto ditto	Ditto	Ditto	Ditto	380 „	168¾	Ditto	Ditto ditto
387	Ditto ditto No 12	Ditto	Ditto	Ditto	480 „	213¼	Ditto	First mixture made with river water
388	Ditto ditto	14 days	Ditto	Ditto	920 „	408½	Ditto	

Numbers	Description	Age	After what time immersed	How long immersed	Weight in lbs supported before breaking on an area of $1\frac{1}{2}'' \times 1\frac{1}{2}''$	Breaking weight per square inch	Quantity of water used in mixing the cement	Remarks
389	Indian Portland Cement No 12,	8 days	24 hours	6 days	350 lbs.	155	30 per 100	
390	Ditto ditto	Ditto	Ditto	Ditto	530 „	$235\frac{1}{2}$	Ditto	
391	Ditto ditto	Ditto	Ditto	Ditto	620 „	$275\frac{1}{4}$	Ditto	
410	Ditto ditto mixed with Nos 1, 2, 5, 7, 8, 9, 10, 11 12 and 13,	Ditto	Ditto	Ditto	380 „	169	Ditto	Mixture made with tank water
412	Ditto ditto	12 days	Ditto	Ditto	410 „	182	Ditto	Ditto ditto
414	Ditto ditto	Ditto	Ditto	10 days	400 „	$177\frac{1}{2}$	Ditto	Ditto ditto
415	Ditto ditto	2 months	Ditto	58 „	800 „	357	Ditto	Ditto ditto
417	Ditto ditto	8 days	Ditto	6 „	330 „	$146\frac{1}{2}$	Ditto	Ditto ditto
418	Ditto ditto	10 „	Ditto	8 „	480 „	$213\frac{1}{4}$	Ditto	Ditto ditto
423	Ditto ditto	Ditto	Ditto	Ditto	380 „	169	Ditto	Ditto ditto
424	Ditto ditto No 15,	8 days	Ditto	6 days	490 „	$217\frac{1}{2}$	Ditto	Mixture made with river water
425	Ditto ditto	Ditto	Ditto	Ditto	650 „	$289\frac{1}{2}$	Ditto	Ditto ditto
426	Ditto ditto	Ditto	Ditto	Ditto	610 „	$270\frac{3}{4}$	Ditto	Ditto ditto

428	Indian Portland Cement,		22 days	24 hours	20 days	Does not break at 1,000 lbs	•	30 per 100	Mixture made with river water
430	Ditto	ditto No 14,	12 „	Ditto	10 „	460 lbs	204¼	Ditto	Rather slow setting Contains clay in excess
431	Ditto	ditto	Ditto	Ditto	Ditto	460 „	204¼	Ditto	Ditto ditto
432	Ditto	ditto	1 month	8 days	28 days	650 „	288½	Ditto	Ditto ditto
433	Ditto	ditto No 16,	8 days	Ditto	6 „	530 „	235½	Ditto	Mixture made with river water
434	Ditto	ditto	Ditto	Ditto	Ditto	430 „	191	Ditto	Ditto ditto
435	Ditto	ditto	14 days	Ditto	12 days	860 „	382	Ditto	Ditto ditto
436	Ditto	ditto	Ditto	Ditto	Ditto	860 „	382	Ditto	Ditto ditto
437	Ditto	ditto	8 days	Ditto	6 days	650 „	288½	Ditto	Ditto ditto
438	Ditto	ditto	16 „	Ditto	14 „	870 „	386¼	Ditto	Ditto ditto
439	Ditto	ditto of dry system	8 „	Ditto	6 „	410 „	182	Ditto	Cement made according to dry system, by passing the mixture through a pug-mill
440	Ditto	ditto	Ditto	Ditto	Ditto	390 „	173¼	Ditto	Ditto ditto
441	Ditto	ditto	Ditto	Ditto	Ditto	490 „	217½	Ditto	Ditto ditto
442	Ditto	ditto	12 days	Ditto	10 days	700 „	311	Ditto	Ditto ditto
448	Ditto	ditto No 15,	21 „	Ditto	19 „	800 „	355	Ditto	Mixture made with river water

Numbers	Description	Age	After what time immersed	How long immersed	Weight in lbs supported before breaking on an area of $1\frac{1}{2}'' \times 1\frac{1}{2}''$	Breaking weight per square inch	Quantity of water used in mixing the cement	Remarks
451	Indian Portland Cement, No 16,	25 days	24 hours	23 days	Does not break at 1,000 lbs		30 per 100	Mixture made with river water
457	Ditto ditto No 17,	8 "	Ditto	6 "	620 lbs	275¼	Ditto	Ditto ditto
458	Ditto ditto	Ditto	Ditto	Ditto	520 "	231	Ditto	Ditto ditto
460	Ditto ditto	Ditto	Ditto	Ditto	610 "	270¾	Ditto	Ditto ditto
462	Ditto ditto	1 month	Ditto	28 days	950 "	422	Ditto	Ditto ditto
463	Ditto ditto No 18,	8 days	Ditto	6 "	540 "	240	Ditto	Ditto ditto
466	Ditto ditto	Ditto	Ditto	Ditto	640 "	284¼	Ditto	Ditto ditto

B

Statement of Experiments made with Michele's Testing Machine, showing the tensile strength of Margohi Cements

Numbers	Description		Age	After what time immersed	How long immersed	Weight in lbs supported before breaking on an area of $1\frac{1}{2}'' \times 1\frac{1}{2}''$	Breaking weight per square inch	Quantity of water used in mixing the cement	Remarks
169	Margohi Cement No 2A, Sand,	1 1	3 months	4 days	2 months 25 days.	580 lbs	$257\frac{1}{2}$	25 per 100	Cement made by Mr Fouracres, Exec Engineer, Dehree Workshop Division, of very fair quality
174	Margohi Cement No 3A, Sand,	1 1	Ditto	Ditto	Ditto	410 "	182	Ditto	Ditto ditto
180	Margohi Cement No 4A, Sand,	1 1	Ditto	Ditto	Ditto	480 "	$213\frac{1}{4}$	Ditto	Ditto ditto
205	Margohi Cement No 5, Sand,	1 1	7 months	24 hours	6 months	650 "	$288\frac{1}{2}$	Ditto	Ditto ditto
207	Margohi Cement, Sand,	1 1	Ditto	Ditto	Ditto	700 "	311	Ditto	Ditto ditto
210	Margohi Cement No 6, Sand,	1 1	1 month	Ditto	28 days	350 "	$155\frac{1}{2}$	Ditto	Ditto ditto
211	Margohi Cement, Sand,	1 1	5 months	Ditto	$4\frac{1}{2}$ months	510 "	$226\frac{1}{2}$	Ditto	Ditto ditto

Numbers	Description		Age	After what time immersed	How long immersed	Weight in lbs supported before breaking on an area of $1\frac{1}{2} \times 1\frac{1}{2}$	Breaking weight per square inch	Quantity of water used in mixing the cement	Remarks
212	Margohi Cement, Sand,	1 1	5 months	24 hours	$4\frac{1}{2}$ months	530 lbs	$235\frac{1}{2}$	25 per 100	Cement made by Mr Fouracres Exec Engineer, Dehree Workshop Division, of very fair quality
227	Margohi Cement No 8, Sand,	1 1	$6\frac{1}{2}$ months	Ditto	6 months	750 ,,	333	Ditto	Ditto ditto
228	Margohi Cement, Sand,	1 1	$4\frac{1}{4}$ months	Ditto	4 months	Does not break at 1,000 lbs.		Ditto	Ditto ditto
260	Margohi Cement No 5, Dehree Sand,	1 1	1 month	48 hours	27 days	440 lbs	$195\frac{1}{2}$	Ditto	Ditto ditto
261	Margohi Cement,		Ditto	Ditto	Ditto	420 ,,	$186\frac{1}{2}$	Ditto	Ditto ditto
263	Ditto ditto No 10, Dehree Sand,	1 1	Ditto	Ditto	Ditto	280 ,,	$124\frac{1}{2}$	Ditto	Cement carelessly prepared, intermediate lime not separated from it, and stones badly selected
264	Margohi Cement,		Ditto	Ditto	Ditto	300 ,,	$133\frac{1}{3}$	Ditto	Ditto ditto
265	Ditto ditto, Calcutta Sand,	1 1	Ditto	Ditto	Ditto	325 ,,	$144\frac{1}{4}$	Ditto	Ditto ditto
267	Margohi Cement,		Ditto	Ditto	Ditto	347 ,,	154	Ditto	Ditto ditto
268	Ditto ditto No 9, Dehree Sand,	1 1	Ditto	Ditto	Ditto	238 ,,	$105\frac{1}{3}$	Ditto	Ditto ditto

269	Margohi Cement No 9, Dehree Sand,	1 1	1 month	48 hours	27 days	227 lbs	$100\frac{3}{4}$	25 per 100	Cement carelessly prepared
275	Margohi Cement No. 11, Dehree Sand,	1 1	Ditto	Ditto	Ditto	420 „	$186\frac{1}{2}$	Ditto	Good ordinary Cement
276	Margohi Cement,		6 months	Ditto	5 months	700 „	311	Ditto	Ditto ditto
277	Ditto ditto, Calcutta Sand,	1 1	1 month	Ditto	27 days	340 „	151	Ditto	Ditto ditto
278	Margohi Cement,		6 months	Ditto	5 months	690 „	$306\frac{1}{4}$	Ditto	Ditto ditto
280	Ditto ditto No 12, Dehree Sand,	1 1	1 month	Ditto	27 days	350 „	$155\frac{1}{2}$	Ditto	Ditto ditto
281	Margohi Cement,		$4\frac{1}{2}$ months	Ditto	4 months	490 „	$217\frac{1}{2}$	Ditto	Ditto ditto
283	Ditto ditto, Calcutta Sand	1 1	1 month	Ditto	27 days	320 „	142	Ditto	Ditto ditto
285	Margohi Cement,		5 months	Ditto	$4\frac{1}{2}$ months	600 „	$260\frac{1}{2}$	Ditto	Ditto ditto
316	Ditto ditto 4F from one of the 25 bags, Dehree Sand,	1 1	1 month	72 hours	26 days	160 „	71	Ditto	Cement spoiled by the rains in transit to Calcutta, but which were not besides carefully prepared
317	Margohi Cement,		Ditto	Ditto	Ditto	310 „	$137\frac{1}{2}$	Ditto	Ditto ditto
318	Ditto ditto,		Ditto	Ditto	Ditto	260 „	$115\frac{1}{2}$	Ditto	Ditto ditto
319	Ditto ditto 4 6S from ditto, Dehree Sand,	1 1	Ditto	48 hours	27 days	270 „	120	Ditto	Ditto ditto
320	Margohi Cement,	•	Ditto	Ditto	Ditto	240 „	$106\frac{1}{2}$	Ditto	Ditto ditto

P D.

No CXCIX.

DRAINAGE OF MADRAS
[*Vide* Plates XXXIII and XXXIV]

Report by W. CLARK, ESQ , *M Inst. C E , Drainage Engineer of Madras, to the Secy to Government, D. P. W , Fort Saint George.*

Madras, April 1875

IN November last I was honored with instructions from the Secretary of State for India to proceed to Madras, for the purpose of laying out a scheme for the drainage of the town

In conformity therewith I proceeded by the earliest opportunity, and arrived in Madras on the 12th December, 1874 I now have the honor to report the completion of my labors, and to forward the plans, sections and estimates of the various works I propose should be executed, for submission to Government

During the years 1864-5, Major Tulloch, R E , had very carefully considered the whole question, and I have had the benefit of his report and plans to aid me This report is so full and complete on the various physical peculiarities of the district, its general features and conditions, that I need do little more than summarise what he has stated

The town stands on a sandy plain, the lowest part being from 2 to 6 feet, and the highest 16 to 24 feet above mean sea level, water is found in all parts of it, a few feet above or below mean sea level

The rainfall averages about 50 inches per annum, which falls almost entirely during three months, and of this 20 inches in one month is not unusual. In fact the rain comes chiefly in the form of heavy storms at intervals, rather than as light rain of considerable duration

I have also had the benefit of information contained in Dr Cornish's

Division	Villages.	Population	Percentage to the gross Population	Total No of Houses		No of Houses — Tiled — No of Houses	No of Houses — Thatched — No of Houses.	Population included in the area to be drained	Population in each area to be drained	Area of divisio s in square miles	Area drained approximate
1	Tondiarpettah,	35,240	8 9								
	Washerman's Pettah,	6,409	1 6					6,409			
	Monegar Choultry,	426	0 2	10,912	307	5,547	5,058	426		5 31	75
	Royapooram,	11,089	2 7					11 089			
	Cassimode,	12,383	3 1					12 383	30,307		
	Total,	65,547	16 5								
2	Peddoo Naick's Pettah,	65 629	16 6								
	Big Parcherry,	5,179	1 3	7,493	2,096	5,003	394			0 74	
	John Pereira's,	2,930	0 7								
	Fort Saint George,	1,588	0 4								
	Total,	75,326	19 0					75,326			
3	Moothealpettah,	32,062	8 2	5,762	1,442	3,912	408			0 91	1 65
	Uttapauliam,	18,895	4 7								
	Total,	50,957	12 9					50,957	1,26,283		
4	Gunpowder Mills,	641	0 2								
	Perambore,	5,650	1 5	1,492	65	964	463			3 88	
	Veysarapaudy,	3 500	0 8								
	Total,	9,791	2 5								
5	Choolay,	15,000	3 8					15,000			
	Pursewalkum,	19,006	4 8					19,006			
	Pereamoot, New Town,	11,275	2 8					11,275			
	Vepery,	4,500	1 2	7,533	552	5,771	1,210	4,500		2 44	2 44
	Poodoopettah,	3,774	0·9					3,774			
	Egmore,	4,392	1 2					4,392			
	Comaleeswaram,	7,544	1 8					7,544	65,491		
	Carried forward,—Total,	65,491	16 5	33,192	4,462	21,197	7,533		2,22,081	13 28	4 84

Division	Villages	Population	Percentage to the gross Population	Total No of Houses	No of Houses — Terraced — No of Houses	No of Houses — Tiled — No of Houses	No of Houses — Thatched — No of Houses.	Population included in the area to be drained	Population in each area to be drained	Area of divisions in square miles	Area drained approximate
	Brought forward,			33,192	4,462	21,197	7,533	.	2,22,081	13 28	4 84
6	Kilpauk, .	5,222	1 4	2,843	212	1,513	1,118		.	4 16	..
	Chetput, .	2,611	0 6								
	Nungumbaukum,	7,704	1 9								
	Mackay's Garden,	3,853	0 9								
	Total,	19 390	4 8								
7	Poodoopaukum,	6,087	1 5	9,537	676	8,263	598	6,087	.	1 32	1 32
	Chintadripettah, .	15,120	3 8					15,120			
	Narasingapooram,	3,046	0·7					3,046			
	Triplicane, .	33,258	8 3					33,258			
	Teeroovateswarampettah,	12,057	3 1					12,057	69,568		
	Total,	69,568	17 4					.	2,91,649 5,255 2,96,904		6 16 31
8	St. Thome,	20,575	5 2	6,169	235	4,431	1,503	20,575	20 575	4 40	1·01
	Alwarpettah, .	1,163	0 2			.					
	Royapettah,	5,255	1 3					5,255			
	Meersaib's Pettah, .	2,050	0 5								
	Kistnampett,	5,193	1 3								
	Tenampettah, .	7,246	1 9								
	Total,	41,482	10 4	51,741	5,585	35,404	10,752		297 479	*23 16	7 48

Total Population, 3,97,552

* To this must be added the area of unoccupied portions, such as the Esplanades, Island, Government House, Chepauk Ground, &c , which makes up the total area to 26 83 square miles

Census Report, which gives more accurate data as to the number of Population, Houses, &c, than existed in 1865

Since that period also, Madras has been provided with a water supply which has an immediate and most important bearing on the subject of drainage, the more abundant the use of water, the more perfectly is the filth carried away in suspension in sewers

Facilities for obtaining an abundance of this necessary of life leads to its larger use for domestic purposes, and the necessity for its more perfect removal thereafter becomes more urgent, for in the absence of proper drainage, not only is there a probability of larger absorption of fluid filth by the subsoil of the town, but evaporation, which is after all the principal means of removal from stagnant and inefficient drains, adds greatly to the generation and spread of malarious influences

The city, for Municipal purposes, has eight divisions, which, with the number of inhabitants in each, and its area, is arranged as shown in the tabular statement on pages 239 and 240.

No 1 Division comprises the district of Royapooram and Tondiarpett, and lies to the northward of the Railway at its sea side terminus, it is comprised between the sea on the east, and Cochrane's Canal on the south

The southern portion of this area, about three-fourths of a square mile, is thickly inhabited, and will eventually be included in the drainage scheme

The 2nd and 3rd Divisions comprise the whole of the Black Town, and the Fort St George, it extends from the Railway on the north, to the river Cooum on the south, from the sea on the east, to Cochrane's Canal on the west

These Divisions are about 1 65 square miles in area, the population amounts to 1,26,283 by the last Census Report

The average number of population to the square mile is 98,732 in the 2nd, and 57,249 in the 3rd, Division, and the number of inhabitants to each house averages 10, or about double the density of the most crowded European cities

The 4th Division is entirely a suburban district, and not included in the Drainage Scheme

The 5th Division area is about $2\frac{1}{2}$ square miles, for drainage purposes it is divided into two, the first including Choolay, Pursewaukum and Vepery The second, New Town, Poodoopett, Comeleeswaram and Egmore—portions of this area are also densely populated, amounting to

13 8 persons in the 'tiled' class of houses, which are about three-fourths of the entire number

The 6th Division is suburban, and is not included in the Drainage Scheme

The 7th Division includes Chintadripettah and Triplicane, this also for drainage purposes is divided into two districts The population here averages from 7 to 8 persons in each house of the better class Its area is a little less than one and a half square miles

The 8th Division comprises Saint Thome, Royapett, and four other villages, of these Royapett is adjacent to Triplicane, and is included with it in the drainage arrangements

Saint Thome, which contains about one-half of the 41,482, constituting its entire population, is one square mile in area,—it is too distant to be included in the general scheme of drainage, but its topographical features and proximity to the sea admit of a separate small scheme being devised for its drainage, which will be discharged into the sea in two places, the estimate for this work is included with the other

The rise and fall of the tide is about three feet, and I have assumed that the mean sea level is that taken by Major De Haviland in 1821, as 6 feet 10 inches below the mark cut by him in a stone fixed in the escarp of the North Ravelin of Fort St George

The datum to which the levels are referred in the plans and sections accompanying this Report, is assumed to be 20 feet below the mean sea level, to avoid the use of + and − quantities

The prevailing winds in Madras are supposed to cause the currents observed on the coast From February to October, winds varying from South-West to South chiefly prevail, they cause a more or less southerly littoral current, and continue nearly nine months in the year.

During the cold season, November to January inclusive, three months, the wind comes from North and North-East, with a corresponding change of the current,—this is of importance in connexion with the position of the outfall which has been chosen for the drainage system into the sea. This point is about two miles north of Black Town, it was selected by Major Tulloch for his drainage scheme, and I quite agree with his reasons for its adoption, it is at a sufficiently remote distance—about two miles from Black Town—to prevent any apprehension of inconvenience

The present drainage of Madras is entirely of a 'surface' character,

save where a few of the larger sewers near their outfalls have been covered over

The smaller drains are usually about one foot square, constructed of brickwork, one on each side of the street, these receive all the slops and fluid filth of the houses, and conduct it to the main outfalls

These are the sea—the River Cooum,—and Cochrane's Canal, which is a tributary of the Cooum.

As a sample of surface drainage, those who advocate that system may here see a fair example, a system of surface drainage which has doubtless been the result of careful enquiry and expensive addition from time to time during many years How utterly it fails to remove without nuisance the matters discharged into it, will readily be admitted by any one who will take the trouble to inspect the daily cleansing, and breathe the atmosphere then pervading the locality These drains appear to be carefully attended to by the Sanitary Officer and his subordinates, but no amount of attention can render, what are in most cases stagnant receptacles of filth, otherwise than objectionable

These drains also receive the rain water and conduct it to one or other of the outlets above named, and it is only on such occasions as a heavy storm that they are thoroughly scoured out, and for a brief period cease to be a nuisance

The very small elevation of a large portion of Madras above the mean sea level, 6 to 8 feet only, and one and a half feet less at high water, renders the discharge of the sudden and violent tropical storms a matter of some difficulty

Flooding of the lower parts of the town is not uncommon, which it would be impossible entirely to prevent, even if an expensive system of underground culverts be provided for the purpose

Very early in my enquiry I was led to determine the necessity for omitting from the scheme any provision for storm water The area of the town is so large and the distances so great, that any attempt to deal with it in the way of underground sewers would have entailed an expense quite beyond the means of the town to execute, as judged by the assessment value of the houses

An additional reason for excluding the storm water arises from the impossibility of making any provision which shall *entirely* remove the inconvenience of floods during the periods of storm

The utmost that could be done within any reasonable cost, would be the construction of sewers to remove one quarter inch of rainfall per hour, as however this amount is exceeded, one inch falling not unfrequently in that period, it is evident on such occasions that the streets would be flooded, and the benefit would then be confined to the somewhat more rapid removal of the flood water when the storm had subsided

Whether this would warrant the increased expenditure is matter for question, there would be an undoubted advantage attending such an arrangement in many ways, the old surface drains would entirely disappear, footpaths forming a marginal channel for conducting the surface water into the nearest entrance grating, would add greatly to the appearance of the streets, and the segregation of the pedestrian passengers would facilitate traffic and personal safety, but it would be a surface improvement after all, not actually required for the removal of filth, and I have, therefore, in consideration of the greater cost, certainly three times, decided to exclude the surface drainage

The covering in of the present surface drains would of itself be a great improvement, but it would be accomplished at a cost of about six annas per foot, or double that amount for two sides of the street, seeing then that there are 125 miles of street to be sewered, I have omitted to include the cost (about 5 lakhs of rupees) from the estimate, because it is a surface improvement, one to be dealt with after the more pressing drainage arrangements are provided for

It is however probable that when, as I propose, these surface drains shall be kept for the sole purpose of conveying away the storm water, that improvements may be made

The principal outlet for the present drainage of Black Town is a large sewer, which occupies the site of a former nullah, in what are now Umpherson and Davidson's streets, and a portion of Popham's Broadway, both ends of the sewer are carried to the sea, the northernmost near Old Jail Street at the north end of Black Town, the southern one near the Fort. Into this sewer is poured all the fluid filth of about two-thirds of Black Town, and its 1,26,000 inhabitants, here it stagnates till eleven o'clock at night when both outlets are opened, with doubtless a very necessary discharge of the filth, but with an amount of nuisance which is spoken of by those who are exposed to it with superlative disgust Various expedients have from time to time been devised, for less-

ening the evil a ventilating shaft has been erected to permit the escape of the stagnant abomination without result, what is now called Kellie's Column remains to indicate that attempt, some years since a windmill was erected to pump out the sewage, but it did not remove the nuisance, and more recently a steam engine has been erected for the same purpose, but it is not now in use, the various papers placed at my disposal show that for many years past, repeated attempts have been made to remove this monster nuisance, but in the absence of a large and comprehensive scheme for dealing with the whole question, the desired result has never been realized, and the Black Town sewer is now as famous for its potency as ever

Several smaller sewers discharge into the sea, and the remaining portion of Black Town is drained into Cochrane's Canal, which communicates with the river Cooum, and both are the subject of loud complaint from those who reside within their influence

By far the largest portion of storm water falling on the 27 miles of the Municipal area finds its way into the river Cooum, and about one-half the drainage in the dry season

The outlet of this river to the sea is usually closed from February to October, including the hot season During this period the river is in fact a tank, receiving about one-half of the fluid filth of the town Organic matter thus becomes mixed with brackish water, and produces the inevitable result, an offensive smell and a more or less malarious atmosphere in its vicinity

Moreover the level of the water in this shallow pool falls gradually to about low water level of the sea, and a large surface of seething mud highly charged with decomposing filth exposed to the action of the sun

It is however quite a mistake to attribute to the great luminary any of the evils which result, his active influence is ever exerted for good Where filth exists, the effect of the chemical as well as the calorific rays is to promote the purity of the atmosphere, and the most potent of the poisons resulting from decomposing filth are found in those open but stagnant drains and ditches where they seldom or never penetrate

The last published Municipal Report is for 1871-2, which gives the following table of death-rate in the Great Cities of India —

Madras, . . .	33 4 per mille
Bombay, ...	25 0 "

Calcutta, ..	23·7 per mille
Lahore,	28·5 "
Nagpore,	22·8 "
Delhi,	41·3 "
Agra,	26·3 "
Lucknow, .	25·5 "

Madras owes much to its proximity to the sea, and the purifying influences of the sea breeze, but notwithstanding all this, its mortality amounted to 13,215 persons, or 33·4 per thousand, while 40 per cent of this was due to Zymotic diseases, and there were thus 5,290 more deaths than should have been, had no sanitary evils existed within its boundaries.

The death rate for Madras, obtained from the Sanitary Commissioner's office, for the past four years is—

1871, .	28·96
1872, . .	35·26
1873, . .	36·7
1874,	37·1

The drainage of other portions of the Town area, Chintadripett, Komlasvarar Covil, and Pudapauk, drain into the Cooum.

Triplicane has two outlets to the sea, similar to the Cooum, much smaller but even more potent.

Milapore and St. Thome have another, these three small rivers are shut off from the sea for about ten months of the year, for they are sooner closed by the shifting sand at the shore, than the larger river, and the stagnant pools they form are even more strongly impregnated with decomposing matter causing an insufferable nuisance.

Beach Road, which is the evening resort of the European population, is a fine road, extending uninterruptedly a distance of 4½ miles from Old Jail Street to St. Thome.

Here the cool evening breeze from the sea in its curative and invigorating influence has won for it the term of 'Doctor.'

How thoroughly enjoyable is this evening drive, and its ameliorating effect on the Indian climate, every one will be ready to admit, but it has this very modifying condition, it must be approached judiciously. A drive along this 4½ miles is not altogether pleasant or enjoyable, at intervals of one mile, from the starting point at Old Jail Street the sewer abominations are felt. The two outlets of the Black Town sewer are

first passed, then the Cooum which becomes very offensive when its communication with the sea is cut off by the 'bar' Then at intervals of half a mile, come the three smaller channels or pools which are always, according to my experience, most offensive

Six stinks "all well defined," must completely mar what would otherwise be almost unrivalled in Indian stations, as a place of healthful exercise and recreation

It is quite evident, I think, that the condition of the Cooum would be immensely improved by keeping open the communication with the sea, so as to admit a fresh supply of water with every flood tide, and thereby dilute—and if the drainage works I now have the honor to propose be carried out,—eventually and entirely remove the nuisance arising from its present misuse

The three smaller streams above alluded to will only be improved when the sewage which now flows into them is entirely diverted into other channels for disposal

I am of opinion there would be but little difficulty in keeping open the communication between the Cooum and the sea at all periods of the year, and if this can be done, the river will then be at all times in the best condition for receiving the surface drainage I had the honor to forward for submission to Government a memorandum on this subject, which will be found at the end of this Report

I may now generally describe the principles and operation of the scheme which I have the honor to submit for the approval of Government

It is intended to remove

1st The fluid filth proceeding from houses and manufactories,

2nd The subsoil water, from those localities where it is found in the soil near to the surface,

3rd The excreta of the population

The fluid filth from houses comprises the cooking and bathing water, urine, and slops of all kinds that can be removed in running water

It does not include ashes, entrails of fish and fowls, bones, cow dung or any solid substances which should be removed by the Conservancy carts

The quantity of this fluid filth, or 'house drainage' is represented by the water supply, which after having performed its various uses should be removed by the sewers, and for the purposes of calculation, I have

assumed that the supply is 20 gallons per head of the population residing in the divisions to which it is proposed the work should extend, these are given in a tabular form at pages 239 and 240

The new source of supply to Madras is said to be capable of giving 40 gallons per head to the entire population, a quantity I think not likely to be required, but which provides a satisfactory reserve for periods of drought

The present consumption is said to be about 7 gallons per head, it is limited to this in consequence of there being, at present, but a small number of houses supplied direct from the mains, for which an extra charge is made, only a limited number of connections are allowed in each street, so as to prevent any undue decrease of pressure

In the comparatively few streets to which the pipes extend, the applications for connections are numerous, and there appears to be no hesitation about incurring the expense of laying on the water to their premises by the owners in those favored localities, about 100 houses are so connected

The people, however, generally resort to the public fountains, and carry the water to their houses, how great a labor this is, will be best seen when the aggregate amount is considered

The total population of Madras at the time of the last Census, in 1871, was 3,97,552, at the rate of one gallon per head the weight to be carried is 1,774 tons, the distance of the fountains apart averages $\frac{1}{4}$ mile, one-half this distance is therefore the maximum distance the weight is carried Seven gallons per head amounts to no less a quantity than 12,418 tons, nearly all of which has to be carried to the houses of the people

The water would doubtless be a far greater boon than at present, if this amount of daily labor could be reduced, by a more extended means of distribution

I am informed that all the larger pipes necessary for an extended consumption have already been laid, what is now required would therefore be confined chiefly to a longer length of the smaller pipes

There can be no doubt, I think, that with increasing knowledge of the use, and value of an abundant supply of water, some extension of the pipe system will be made, and I have, as above stated, taken the usual quantity of 20 gallons per head for the purpose of calculation

The quantity of 20 gallons per head of the population is therefore the

quantity which the drainage system should remove and which comes under the denomination of house drainage

This consumption is not, however, uniform during the 24 hours, it is greatest between the hours of 7 and 10 in the morning, and I have assumed that one-half or 10 gallons of the daily supply is used during six hours

The next item is the subsoil water, this varies, of course with the various seasons, wet and dry, of the year It is greatest during the periodical rains, but it continues for a considerable period after their cessation, varying with the character of the subsoil, while sand parts with it readily, clay retains it for a much longer period

During the rainy season of the year, the quantity of subsoil water in Madras will probably fully equal the amount of the water supply at 20 gallons per head, and this, as I have explained, will continue for a considerable period after the rains have ceased Under the head of subsoil water, I propose therefore to provide for the removal of a quantity equal to the water supply, 20 gallons per head, flowing away uniformly during the 24 hours

The last item to be received by the sewers, is the night soil and excreta of the population On this subject authorities are not agreed, and very divergent are the opinions offered

Various systems have been brought forward and have found advocates Among these are the Liernur, dry earth, and charcoal systems—and many other substances and methods have been used for obviating the nuisance of its removal, while many are the objections urged to the principle of the water carriage system in sewers Without entering into any long discussion of the subject, I would call attention to the fact, that whether the night soil be admitted to the sewers or not, the cost of the drainage system will not be effected one single rupee, the quantity to be thus removed is so small compared with that the sewers are competent to remove, that the small addition amounts practically to nothing

With the exception of the Liernur system (which is said to cost about £2 per head of the population, about three times the cost of the entire drainage works I am about to propose) all the various methods suggested for the disposal of this material involve the cost of carriage and manual labor Up to the present time, as far as I know, not one of them has been successful in an economical point of view, and an expense

is entailed on the community or company as the case may be, about equal to the cost of carriage and the substance with which it has been mixed, Liernur himself up to this time has not, I believe, been able to show any financial results, though he has proved the possibility of removing the substance by his apparatus

Sewage irrigation has been for several years gradually extending, by the water carriage system, no further expense is required when the water and proper drainage works are available, the handling of the substance is entirely unnecessary, moreover it passes away at once without any stoppage or detention, and is out of the limits of the populated area before decomposition can take place

The water carriage system will, I think, be readily admitted to be the cheapest where water is available and abundant, as it should be in Madras, if the pipes for its distribution are extended throughout the town

This not being the case it is too much to expect that the native inhabitants will carry an additional quantity of 20 lbs per head (which would be sufficient) or an additional 3,548 tons of water daily for this purpose, and the night soil will not to any great extent, under the present state of the water supply, be put into the sewers

I would, however, urge that every encouragement and facility be given to those who are inclined to adopt this plan, first, because it reduces the necessity for a most disgusting occupation also because it reduces an inevitable nuisance, and lastly, because by sewage irrigation I believe it will find its most profitable employment in increasing the productive power of the soil, which is its proper and legitimate use

I consider also that what in Bombay is known as the Halicore cess, a separate and distinct tax paid for removing excreta from the houses, is a legitimate source of revenue, which those of the inhabitants who may arrange for its removal by the use of the sewers, and a larger consumption of water will entirely escape

The arrangements which I have made include the following separate and distinct areas for drainage —

First —North of the Railway
Second —Black Town
Third —The Fort
Fourth —Pursewalkum, Egmore and Poodoopettah.
Fifth.—Chintadripett.
Sixth.—Triplicane, and
Seventh.—St. Thomé

The first of these is the only portion to which my scheme in detail has not extended, up to this time the levels are not taken, but it will be comparatively easy for any one who may have charge of the work to do this, as a brick sewer extending from the sea beach along Old Jail Street, and capable of conveying its drainage in the quantity I have mentioned is provided This sewer will also at once be available for draining the Government buildings on the North side of, and adjacent to Old Jail Street

In the second or Black Town Division, there is a considerable variation of surface, there are two well defined ridges parallel to the sea shore with the street known as Popham's Broadway in the valley between them, the level of this and several adjacent parallel streets is from 6 to 7 feet only above mean sea level

The ridge on the West is occupied by Salay, or Mint Street, and from this ridge the drainage on the West side is into Cochrane's Canal

Along Umpherson and Davidson's Streets and a part of Popham's Broadway, is the large sewer which occupies the site of an old stream, and terminates at both ends in the sea

Along Popham's Broadway it is intended to construct a brick sewer with a fall of four feet per mile towards Old Jail Street, where it meets with another brick sewer for draining Royapooram, extending from North Beach Road along Old Jail Street

From the junction at Popham's Broadway, it is still continued along Old Jail Street to Mooneappen Moodelly's Street, along which it is carried to Peddoo Naick's Lane, here it leaves the public thoroughfare and is carried through Garden Land till it reaches Annapilly's Street, thence it continues through Public Land, on which there is a Wood Bazaar, and the Cobra Tank to Wall Tax Road

Here it joins the Pumping Station which it is proposed to place on the open space of ground at the foot of the Elephant Gate Bridge and close to the canal

This point is nearly central to the area to be drained, and its adoption insures the best available inclination to the sewers, while it avoids excessive depths.

The Southern portion of Black Town and the Fort, will be drained into a brick sewer extending along the Wall Tax Road, to the Hospital Gate Road, as far as Evening Bazaar Road, here the brick sewer, which

is laid at an inclination of four feet per mile terminates, and a 12-inch pipe is carried into the fort at an inclination of 1 in 625

Crossing the fort ditch below the level of the water, it will be possible to place a valve in the pipe (which will here be of iron) by which this pipe can be flushed should occasion require

The main sewer is carried from the Pumping Station by a 3-feet iron syphon under the canal, through the People's Park, to Sydenham's Road, at an inclination of two feet per mile

Here it sends off a branch through Choolay Bazaar Road for a distance of 1,350 feet It is then continued along Vijiavignaswarar Covil Street by a double 15-inch pipe, at an inclination of 1 in 700 up to Perambore Barracks Road, from this point a single 15-inch pipe proceeds along Vencatasabuthen Street, and a low swampy portion of land, which is called Oday, and conveys away surface water in the wet season

From this point it is carried along Condapah's Moodelly, High Road, into Pursewalkum High Road at the same size and inclination Here it is reduced to 12 inches in diameter, and the inclination is made 1 in 600, it terminates at Venethetha Moodelly's Street

From the Choolay Bazaar Road the Main sewer extends along Sydenham's Road to near Lawe's Bridge over the Cooum River, which is crossed by an iron syphon two feet in diameter, laid below the bed of the stream into Chintadripettah, here it enters Iyah Moodelly's Street which it traverses its whole length to the Waller's Road, it is then laid for a short distance through Nursingapooram Parcherry, to the compound occupied by Messrs Taylor's Livery Stables which it crosses diagonally, and enters Blacker's Road, along which it proceeds to Wallajah Road

From this point a branch 12-inch pipe sewer is laid along Mount Road at an inclination of 1 in 400 as far as Woods' Road

The brick sewer is continued along Triplicane High Road, to the Nabob's Palace, across the compound of which a 15-inch pipe is laid through Chellapilliar Covil Street to Pycroft's Road, and terminating at Peter's Road, where it receives the sewage of Royapett

In the Triplicane High Road, the brick sewer is continued to the crossing of Pycroft's Road, from this point it is extended to Peter's Road by a 15-inch pipe Another branch pipe is laid towards the East in Pycroft's Road to Vencataranga Pillay's Street The whole of these main sewers except where otherwise mentioned, have an inclination of four feet per mile.

One other branch remains to be described, this extends from Sydenham's Road, along Poonamallee Road, to the East side of the Scotch Church compound, along which it is carried to Jordan's Road, it is then continued along this and Whannell's Road, to Pantheon Road, here the brick sewer terminates, and a pipe 12 inches diameter is carried through Lang's Garden Parcherry to Harris' Road, at an inclination of 1 in 765

From Jordan's Road a 9-inch pipe sewer is carried along male Asylum Road to Egmore, at an inclination of 1 in 400

I have thus described generally the position and particulars of size and inclination of the main sewers, they are all adapted to the work they have to do, and are sufficient for the purpose, in most cases they are laid below mean sea level, and will permanently receive subsoil water, even when other portions of the system during the dry season of the year may cease to do so

The conditions under which they are placed will necessitate no especial provision for flushing

Deposit in sewers chiefly consists of road sand—the material of which the road is composed when ground down by the action of wheeled vehicles, on the occurrence of the first shower of rain, this road sand is washed into the sewer more or less according to the precautions taken to arrest it by 'Gully Pits,' where the storm water is first received, but however perfect the action of these pits may be in arresting the heavier particles, a large quantity is carried into the sewers,—many hundred tons are thus washed into the sewers of a town as large as Madras by a single shower, and expense is usually entailed when its removal by hand, is necessary

For this purpose, the brick sewers were only a few years ago generally constructed of brickwork, of a size to admit of the entrance of men for the purpose of cleansing them, and without reference to the quantity of fluid filth they have to remove, sewers were thus frequently made too large for the work they had to do It is now well known that the more concentrated the flow of any given stream, the greater is its power to keep itself clear and free from deposit, this led to the adoption of the oval shaped sewers, where the invert is generally struck with a radius not exceeding that of a pipe sewer, hence the oval brick sewer combines both advantages

The only legitimate argument for making a sewer large enough for a man to enter it, is for the purpose of making good the house connections

But in the scheme which I now propose, it is intended to exclude the surface water, and this source of deposit material is at once got rid of, while of the household processes by which sandy material is produced, probably that of scouring brass cooking utensils in this country is the only one from which such deposit could occur

There is, however, every reason why the cleansing of the sewers should be provided for When pipe sewers are laid in sandy soil, it is always necessary to thoroughly cleanse them of the sand which unavoidably enters the pipes during the process of laying, especially if it happens to be in wet and difficult ground

For the purpose of cleansing the pipes, my practice has been to lay them in straight lines, and never on any account to depart from this rule At a distance not exceeding 300 feet, a 'manhole' is constructed, this is a well extending from about one foot below the surface of ground, where it is covered by an iron cover, to the depth of the sewer, it is usually of oval from three feet six inches long, by two feet in its greatest width, it is sufficiently large for a man to enter, if the pipe sewer is clean he is able to see light at the other end, as a perfect circle, if it be obstructed, a split bamboo with a small line attached can be forced through to the next manhole, this is made to draw a light chain with a circular iron scraper made for the purpose

If then there be any quantity of water running through the pipe, by the help of the agitation caused by drawing the chain back and forward, it is speedily removed and carried down the pipe to the next manhole

All pipe sewers are thus easily cleansed if necessary If the pipes be properly laid and all entrances to house drains trapped by syphon traps, *as they should be*, it becomes exceedingly difficult to put anything into the sewers which will stop them

As the same velocity can be obtained by a given quantity of fluid in a pipe as in a brick sewer, and if the pipe be of sufficient size to do the work required of it, it is manifestly more desirable to put down the cheaper small pipe, than an unnecessarily large brick sewer, and this principle has guided me in laying out the main sewers which I have above described

In the arrangement of the smaller pipes, the same principle has been followed, save that when the quantity of fluid to be passed through a pipe is very small, it becomes necessary to assist its self-cleansing action by a

better gradient, thus the smaller pipes have better falls than the larger into which they discharge

In the present scheme no 6-inch pipe, which comprises five-sixths of the whole, has a smaller gradient that 1 in 300, or something more than 17 feet per mile, and many of them much more than this

Manholes, such as I have described, at every 200 to 300 feet, are also constructed at every junction of one street sewer with another, in these cases the floor of the manhole is formed by brick in cement into a sort of half pipe channel, having the effect of a curved junction It is also desirable at all junctions of pipe sewers, to give the tributary pipe a fall of from one to three inches to accelerate, rather than retard the main stream

When, owing to the tortuous windings of a line, the manholes would be very close together Lamp holes are adopted in their place alternately with the manholes These are considerably cheaper, being from 9 to 14 inches square only A lamp suspended in them enables a person in the adjacent manholes to ascertain if the pipe be clear, and if not, the position of the obstruction, all these are provided for in the Estimate

From what I have said in page 248, the quantity of fluid to be passed through the sewers will be at the rate of 20 gallons per head of the population, and half of this or 10 gallons will enter the sewers in six hours

To this must be added the subsoil water equal to 20 gallons flowing in uniformly during the 24 hours, or at the rate of five gallons in six hours Thus 15 gallons in six hours may be considered as the maximum flow for each unit, and 15,000 gallons per 1,000 of the population This quantity is 41 66, say 42 gallons per minute

In Black Town, an examination of the Revenue Survey shows that the holdings average 30 feet of frontage

The number of persons residing in each of these is greatest in the 6th Division, where 13 persons reside in 'Terraced Houses,' there however this description of house is not numerous, the 'Tiled House' are more than double the number, and in these 6 7 is the average

In Black Town the greatest number also reside in Tiled Houses, and the average is 10 3, but taking 10 as the average for all houses, then there will be 10 persons residing on every 30 lineal feet of the street on one side, or double the number on both sides, this amounts to 20 persons on every 30 feet, or 2,852 persons per mile, if therefore 2 852 be multiplied by 42, it will give the quantity, 120 gallons per minute

Now a 6-inch pipe sewer laid with a gradient of 1 in 300 will discharge 134 gallons per minute It is evident therefore that in Black Town a 6-inch pipe may be laid so as to receive the drainage of one mile of houses In no case however has this limit been approached in the present scheme, and ample provision is therefore made for the maximum flow of drainage fluid as above calculated.

Similarly all the large sizes are determined, and a margin left for even an increased flow

There is much reason to fear that the quantity to be carried away will be much less than what is shown above, until the water supply is further extended

The larger the quantity of fluid flowing within their capacity, the more perfect the action of the sewers

The pipes are laid as before described in perfectly straight lines, they are bedded in concrete to prevent unequal settlement, and preserve the accuracy of the line both vertically and horizontally Regularity of shape and perfect lines and levels are both necessary to success, and both are attainable

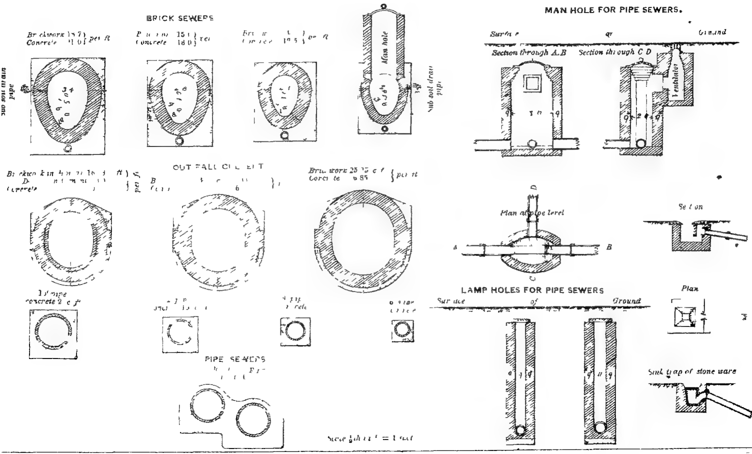
The pipe joints are made with Portland cement for three parts of the circumference, the remaining one-fourth at the top is packed with well tempered clay and covered with concrete This prevents the entrance of sand, but permits small quantities of subsoil water to pass in at the top of the pipe, and thus the subsoil drainage is effected

It is well nigh impossible to make brick sewers water-tight, when they are laid, as they will be here, beneath the permanent level of saturation, most bricks are so porous that the water passes through them It is however, usual to put an agricultural drain pipe through the side wall of the sewer at intervals of 50 feet above the general line of flow, this terminates in a lump of broken bricks on the outside, it admits the subsoil water, and excludes the sand, and by this means also the subsoil drainage is effected

It may be, that owing to the intrusion of some semi-fluid substance flushing may be necessary, one cause of this I have found in semi-fluid cow-dung, which the cow-keepers thus endeavour to dispose of, when they are unable to dry and sell it, in the wet season.

For flushing, the manholes are a great assistance Some temporary expedient such as a ship's 'swab' may be jammed in front of the pipes so

DRAINAGE OF MADRAS



as to prevent the water from escaping, if the manhole then be filled with water by a hose from a neighbouring water main, and the stoppage of the line requiring to be cleansed is suddenly removed, a considerable body, 40 or 50 cubic feet of water may be forced through the pipe and wash it out completely

When constructing brick sewers in ground saturated with water, it is usual to first lay a drain pipe in concrete, a few inches below the level of the sewer, this collects the water from the subsoil, and it is pumped out from small wells or 'sumps' at intervals, this plan enables the construction of the brickwork to be more satisfactorily accomplished than it could otherwise be, and notwithstanding the cost of the drain pipe, it is the most economical mode of proceeding It also enables the coating of cement plaster to be laid on the surface of the bricks, which, if the cement be good, is impervious to water, it prevents their absorbing the sewage, and gives a smooth surface to the channel This cannot possibly be accomplished unless the sewer be kept free from water

Cement plaster for the interior of the sewers is provided in the Estimate

After the sewer is completed, it is usual to fill up the wells or sumps with concrete, and exclude the subsoil water, I have, however, in a few cases left a small space to be filled with agricultural drain pipes placed vertically so as to admit the subsoil water to rise into the sewer from the drain pipe, where these are left, however, there should always be a greater pressure of water tending to enter the sewer, than is due to the depth of the ordinary flow favoring its escape.

Where the sewer is constructed at any considerable depth—four or five feet below the level of saturation—this will usually be the case, and in such cases small fountains remain permanently, and are most useful in keeping the sewer clean, while the subsoil drainage is also provided for

The ventilation of the sewers will be effected by gratings fixed in the road surface near to the manholes and in connexion with them at distance of about 100 feet, these are provided for in the Estimate and shown in the drawings

I have now generally described the positions and the action of the main and pipe sewers for conveying the sewage to the Pumping Station, which, as I have before mentioned, I propose should be constructed near the Elephant Gate Bridge

Three main sewers, viz, from Royapooram and north side of Black Town,—the second from the south end of Black Town and the Fort, and the third from People's Park, which receives all the drainage of Pursewaukum, Chintadripettah and Triplicane All these will be received into a well 30 feet in diameter, at the Pumping Station This well will be sunk 10 feet below the level of the sewers, and the inverts of these will be 8 feet below mean sea level

The work required to be done by the engine will be as follows —

The total population living on the drained area will be (as per Table, page 240,) 2,96,904, 3,00,000 may be taken for calculation

The maximum quantity of house and subsoil drainage may be taken at 42 gallons per minute per 1,000 of the population, page 255

then 300 × 10 lbs × 42 gallons = 1,26,000 lbs
and the lift will be 19 5

630000
1134000
126000

2,457,000 0 foot lbs per minute

$$\frac{2,457,000}{33,000} = \text{70-horse power}$$

When the works are fully completed, the working of 70-horse power effective, will be required during six hours of the day

This power must be supplemented by one-half more, or 105-horse power effective, in the aggregate

For the present, two engines of 35-horse power effective, will be amply sufficient, and the cost of these and the engine house, &c, to contain them is provided in the Estimate

The engines and pumps I propose to erect will be precisely similar to those which in Calcutta have proved successful, with such improvements as experience since their erection has suggested

The principal feature of these combined engines and centrifugal pumps, is a large cast-iron cylinder, extending from a little above the invert level of the sewers, to the top of the outlet culvert, in this case it will be 20 feet high, by 8 feet diameter

On this cylinder the engines, and A frames, carrying the driving wheel are supported, and the vertical shaft and centrifugal pump disc are suspended.

The suction pipes extend from the bottom of this cylinder to a low level in the pump well

The pump disc is formed of two circular metal plates, with a circular hole in the centre The two plates are kept apart by curved division pieces extending from the circular hole to the periphery of the disc, which is open

The disc is attached to the end of the vertical shaft at its lower end, and when in place, is at the bottom of the vertical iron cylinder

The suction pipes are so arranged as to carry the sewage to the circular hole in the disc which is made to revolve with great rapidity

This motion causes the sewage to be thrown out of the disc at its periphery, as it continues to enter at the circular hole at the centre, and with the force necessary to insure its rising in the iron cylinder to the required height above the invert of the outfall culvert The outlet pipe from the cylinder leaves it at a higher level, and thence the sewage flows to its outfall

In the present case, the top of the cylinder will be somewhat higher than the top of the outfall culvert in Mint Street, and the connecting channel between them will be an iron pipe three feet six inches in diameter, laid in Rawmanen Street, up this pipe the sewage will be forced into the outfall culvert by attaining a sufficient height in the pump-cylinder.

I have thus endeavoured to describe the pumping operation in order to show that it can be so arranged as to prevent any nuisance from arising

The pump well will be entirely closed from the outer atmosphere, but a flue will be constructed from it to the boiler furnaces, the pump well will be thus ventilated, and the gas consumed by the engine furnaces

The suction pipes are of iron, air tight in their connection with the cylinder, the top of the cylinder is also closely covered, it is evident therefore that the sewage is not in any way exposed to the air during the process of pumping, and there can be no escape of gas and no nuisance

An apparatus consisting of an air blowing cylinder will be attached to each engine and iron pipes to convey compressed air to the pump well, this pipe terminates in an open perforated pipe laid on the bottom of the well. The use of this is to agitate the sludge or semi-fluid which may accumulate in the well, and mix it up with the more fluid sewage, and so dilute it as to permit its being pumped away, thereby obviating all necessity for manual labor in cleansing the well.

This arrangement has been perfectly successful in Calcutta, where frequently a quantity equal to 600 tons of solid in the form of road grit is disposed of in about four hours

A culvert to convey water from the canal, when required for the purpose, will be provided

The outlet pipe from the pumps, will as above stated, be 42 inches in diameter, of cast-iron, it will be laid along Rawmanen Street as far as Mint Street which occupies the ridge of high ground above referred to, page 251 It is of such a level as to admit of a brick culvert four feet nine inches high being laid beneath the surface, with an inclination of five feet per mile, at its highest point where the iron pipe from the engines joins it, its invert is 10 feet over mean sea level, or 30 feet over datum The total fall in the outfall culvert will therefore be 10 feet, which is thus distributed

3,170 feet 4' 9" × 4 0 oval culvert, fall 5 feet per mile
12,536 „ 5' 0" × 4 6 „ „ „ 2 „ „
3,866 „ open excavation with walling at bottom 4 feet, fall 1 in 3,040

The open excavation is carried through market gardens, and waste land to the sea

At the sea end, a length of 200 feet of 5' 9" × 5' 0" oval brick culvert will be constructed with a further length of 22 feet of stone masonry work in which the junction lengths of a 4' 6" cast-iron pipe will be firmly secured at the margin of the sea This four feet six inch pipe will be continued into the sea for a distance of 100 feet, supported on screw pile jetty work

At the end of the pipe a valve is arranged to close by a float, the object of this is to prevent sea water entering the pipe, while the sewage is allowed to escape freely The level of the pipe is one foot above mean sea level.

The point chosen for the discharge of the sewage into the sea is two miles to the north of Old Jail Street, there are no habitations near, and along the line of the open excavation, it is equally removed from residences of the population

This open portion of the outfall channel can also be made in the form of a brick culvert, of course at some increase of cost, but I have considered desirable that it should be constructed as an open channel, and every facility given to the market gardeners on the line to irrigate their gardens with the sewage, there is no doubt whatever of the result.

The fertilizing value of sewage being thus illustrated, it is to be hoped that some capitalists may be found to take up the question of the utilization of the entire sewage of Madras, any of the waste land lying at a level not higher than 8 or 9 feet over mean sea level, and within a distance of five or six miles of Madras may be irrigated with the sewage without further pumping

There is an enormous area of low land in the direction of the canal which may thus be fertilized Much of it would however, require special works for its drainage, but even this will not be too expensive an operation to exclude its use

Of all the various schemes which have been adopted for the disposal and utilization of sewage, irrigation is the one which has, according to my experience, proved remunerative, which requires no manipulating or manufacturing process, always expensive, previous to use, and which is most readily applied Sewage farms in the neighbourhood of London and other large Towns in England, are rapidly increasing with promise of great success

In England the one great difficulty is the cost of keeping the land clear of weeds, which grow as rapidly as the crops, this is a serious difficulty in sewage farming In India, however, where crops of equal value, sugarcane, tobacco, corn, garden vegetables, and the grasses grow under its influence, most luxuriantly, the cost of manual labor is cheap, and the great difficulty disappears

Having had the management for a short time of a small sewage farm, I can speak with great confidence on this question It is too much to expect that any profit can be immediately realized by the Municipality out of sewage operations of this kind, but after the requisite experience has been obtained, there can be no doubt whatever that capital may thus be profitably employed, and the necessity for discharging the sewage, except on rare occasions into the sea, be avoided

Such is a general view of the drainage sheme I propose for consideration of Government I may now add a few ideas on the subject of material

I have throughout spoken of brick sewers, and the estimate has been made for brickwork of a very superior kind, but the bricks I have seen in Madras are not well suited to this work, though well shaped, and burned, they are too absorbent, the material of which they are made is

not good, and I have included in the estimate the cost of inside plastering with cement, if this is properly done, it is like a coating of smooth stone, and will remove the objection of absorption

I have also provided for a large quantity of concrete in which the brick sewers are to be embedded, this will very materially strengthen them, but it involves considerable expense

It has occurred to me, and I have taken steps to enquire, as to the use of laterite blocks for this purpose in substitution for brick sewers, to be plastered with cement on the inner surface of the sewers

The questions to be solved are, can this material be cut with sufficient accuracy and to the required shape? If so, will the cost be less than that of brickwork? I have very little doubt that all these questions may be answered in the affirmative, some blocks are now being cut of the required shape, and the point may soon be settled

The next question, will Portland Cement adhere to the laterite blocks in the sewage? this will take a longer time to answer, and I would propose that some of the blocks should be cemented and placed in one of the sewers to ascertain if the adhesion of the cement continues perfect under these circumstances, I would advise the continuation of this inquiry

Failing the use of laterite, concrete blocks may, I believe, be employed with advantage, and almost equal economy

So much of the material for these works requires to be of special form, if brick be used, some considerable time must elapse before a commencement can be made, the sewers require almost exclusively bevelled bricks, the manholes wedge-formed bricks, and so on, all this will take time to prepare, but if laterite be used, this loss of time will be wholly avoided, as I am informed there is an abundance of material within 12 miles of Madras and labor to cut it

The drain pipes to be used should be of the best quality procurable, India, according to my experience, though possessing the crude material, has not at present produced pipes with the accuracy of shape required The best English pipes leave little to be desired in this way, not only must the pipes be good, but of even greater importance is the accuracy of the workmanship required to lay them Native workmen when carefully instructed are quite competent to this, and the considerable quantity of concrete provided for in estimate on which to bed them will, I believe, prevent sinkage and insure permanent and good lines

Probably most important to the efficient action of drainage scheme is the *House Drainage*. This is usually left to ordinary workmen who may or may not have the requisite skill and experience. The unanimous opinion of all Sanitary Engineers I have met with, and it is decidedly my own also, is that none but men who are experienced in the work should be permitted to touch it; this of course necessitates the employment of a department for the purpose, where every man's work can be known, and any failure traced to its proper source; where work must be at once covered up and remain unseen, it is too great a temptation for irresponsible and often very ignorant men, to scamp it.

It may, and generally does happen, that on completing a house drain pipe, a length is required to fill up an interval, not exactly two feet (the manufactures' length) and another of the required length is not procurable; it is a material impossible to cut, the consequence is that a broken pipe is put in and an open joint is left, through which the sewage can escape and saturate the surrounding soil, and which may also admit the earth and cause a stoppage in the pipe.

There are innumerable ways in which the efficiency of a stoneware pipe house drain can be impaired in its efficiency without actually failing; the result may be, and often is, sickness in the household; and from such causes the bad workmanship of incompetent workmen, house drainage as a system is actually in some cases condemned as an evil rather than a good; every one who has experience in the subject will be able to confirm what I have now stated, and as to the general inefficiency of the work done by persons without the necessary especial experience.

I have spent many years in endeavouring to perfect the scheme of drainage in Calcutta, but I entertain serious apprehensions that the good which has been done will be very considerably diminished by the 'free trade' in house drainage which has been encouraged, notwithstanding my repeated remonstrances; and in Madras I would commend this subject to the consideration of those who may be entrusted with framing the rules and regulations under which such works are undertaken.

All these evils would be avoided by a responsible department who should not only construct, but give necessary attention to the working and maintenance of the drainage, at the expense of the owners.

I am of opinion also that every facility should be given for the economical construction of the house drains. The mass of the people who have

to pay for them are poor and can ill afford to do so, the order to expend 40 or 50 rupees is to them a serious difficulty, usually they are desirous of having the benefit of the improvement, but oppose it rather than have to pay for it

In such cases, the Public Health Act of England provides that, the Sanitary authority may execute the work and hold the property as security for payment of principal and interest in a certain number of years

Thus for a loan of Rs 100 with interest at 5 per cent for 5 years, the quarterly payments would be Rs 5-13 to pay off principal and interest in that period

I am persuaded few people would object to the improvement carried out in this way, I would therefore submit for the consideration of the Government, the desirability of such an addition to the Municipal Act as will enable the Municipality to undertake the work of private drainage charging just as much as the work may cost, and obtain re-payment in the form of private Improvement Rates collected in the ordinary way quarterly, with the other Taxes

The actual cost of private drainage of premises is of course dependant on their size, arrangement, and position; it is also dependant somewhat on the width of the road

	RS	A	P
4 inch stoneware pipes cost, landed in Madras, per foot,	0	4	0
Laying in the ordinary way with concrete,	0	6	0
Total per foot,	0	10	0
For a small house the length required may be assumed as 50 feet, at 10 annas,	31	4	0
Cost of connecting house drain with public sewer,	3	0	0
One syphon trap fixed,	3	8	0
Total Rs,	37	12	0
Should a simple privy inlet be added without additional pipe, the cost will be	8	4	0
Total Rs,	46	0	0

This would be exclusive of the cost of cutting walls and repairing brickwork disturbed

The one item of connecting the house drains with the street sewer can be in some degree reduced, by putting in the junction piece when the pipe sewer is laid, if this plan be adopted generally, it will not only reduce the cost by a length of pipe (which must be broken to get it out)

but it will obviate the risk of damage and disturbance to the pipe line which to some extent is unavoidable, moreover, there are some places where the cost of the connection is double what it would be in other places, without any corresponding benefit to the house connected, as when the connection is made with a 9 or 12-inch pipe, in place of 6-inch

In consideration of all the circumstances, I recommend that the junction pipe for every house should be put in as the street sewer is laid, and I have included in my Estimate an amount of Rs 13,055 for this purpose

For efficient record of the position of house drains, it is necessary that a plan should be made of all premises drained, at a scale of 20 feet to the inch, at this scale the position of drain and water pipes, &c, can be accurately shown, each house-owner should be called on to furnish such a plan of his premises on which to lay out the drainage, or pay the cost of it as a part of the house drainage to the Municipality

The 100 feet revenue plan should then be corrected, and filled in with the buildings, which are now entirely omitted, if this be done, at any time when examination of the house drain may be required, it will be possible to ascertain its exact position

The Act empowers the Municipality to supervise all additions and alterations to house drains

The survey of the houses in every street should thus precede the execution of its drainage, as it is only by such means the exact position of the connection can be correctly determined

One other important matter must be borne in mind when arranging the house drains

As the system is not intended for surface water, the inlets to the house drains must in every case be so arranged as to exclude rain and flood water

Most of the houses, especially in the lower parts of the town, are raised two or three feet above the road level If the inlet be so raised to 30 feet above datum, it will exclude flood water, but it must also be raised a few inches at least above the general level of the compound, backyard, or other place where it may be fixed, to exclude rain water, and it must always be subject to inspection by the proper officers

It should also be a regulation that all inlets to house drains be trapped by a syphon trap, guarded by an iron grating, and in the open air, should any pipe drain form an upper apartment or interior of the house be brought to this trap, it should not be connected with the interior Its

continuity should be broken, and the fluid be discharged a few inches above the grating

This does not apply where privy or water closet connections are required, these apartments should be adjacent to an outside wall in all cases and freely ventilated

The soil pipe in the case of water closets should be carried to the highest level the house admits of, and open at the top

Where the premises are large, and several branch drains are constructed, it is desirable to collect them into one pipe and construct a trap in its length before it enters the sewer

As I have before mentioned (page 244), the surface channels will be left open as at present, this leads to a difficulty which it is most desirable should be thoroughly understood

Were these surface channels destroyed, filled up, or covered and cut off from the houses in any way, then the house owners would be compelled to connect their houses with the new sewers, or the filth would be discharged upon the road surface, an intolerable nuisance would be created and speedily suppressed by the operation of the law

Where however the surface drains are left as at present, and house owners are content to allow matters to remain as they are, without connecting their houses with the new sewers, there would of course be no departure from the usual state of things, and this has only to be of frequent occurrence to render the entire work useless

I would therefore strongly urge on the Government the importance of doing whatever portion is taken in hand completely, rather than that an expense should be incurred for the public sewers while the equally important house drains are left to the decision of the owners The result of this would undoubtedly be, in most cases that when expense varying say from Rs 10 to 100 has to be incurred, they will generally see reason why matters should remain as they are and the expense be avoided

I would venture to advise, that in the event of Government adopting the scheme that it should be executed in separate and distinct portions, and each should be well advanced towards completion before another is undertaken The first work I think should be confined to Black Town and the Fort, the greatest existing nuisance would be removed, and I believe, the most benefit derived from the expenditure of a given sum The construction of the Pumping Station, and the outfall sewer, should

be simultaneous with that of the Street sewers I believe that this could be completed within three years, and the remaining portion could then be taken up in divisions as considered most desirable

	RS
The total estimate for Black Town and the Fort is,	7,07,109
The Pumping Station,	1,62,374
Outfall complete,	2,71,451
	11,40,934
Add for Contingencies and Engineering, 15 per cent,	1,71,139
Total Rupees,	13,12,073

Statement of Quantities and Cost of the Drainage Works in the various Divisions of Madras

Description		Black Town and Fort	Chintadripett	Pursewalkum and Egmore	Triplicane and Royapett	Mylapore	Total of each description
							Quantity
6 inch pipe,	Feet	249,576	127,875	33,470	99,743	37,477	548,148
9- "	"	23,375	11,140	760	15,905	4 820	56,350
12- "	"	3 440	920			5,040	8 400
15- "	"	1,000	5,815		9,170		15 985
15- " double,	"		3,260				3,260
Manholes,	No	823	536	114	435	178	2,086
Ventilators,	"	426	272	6	209	90	1,055
Lamp holes,	"	285	64	29	59	12	449
6″-pipe connecting house drainage,	Feet	11,209	5,691	1,885	6,600	3,203	28,588
9″- " "	"	1,401	692	50	1,100	1,068	4,251
Brick Sewer, 3′ 6″ × 2′ 4″ of 2 rings	"	13,215	4,035	4,965	2,805		25,020
" 3′ 6″ × 2 4′ of 3 "	"		1,350				1 350
" 4′ × 2 8″ of 3 "	"	8,260	3,525				11,785
" 5′ × 3′ 4″ of 3 "	"		1,675				1,675
Bell mouth,	No	2	4				6
Side entrance,	"	4	4	1	3		12
Manholes,	"	25	22	10	6		63
Ventilators,	"	25	22	10	6		63

The total cost of each division and work as given in the detailed Estimate is as follows —

	RS
Black Town and Fort,	7,07,109
Pursewalkum and Egmore,	4,12,568
Chintadripett,	1,06,007
Triplicane and Royapett,	3,68,273
Mylapore,	94,197
Carried forward,	15,88,154

		RS
	Brought forward,	15,88,154
Out-fall complete,		2,71,451
Pumping station,		1,62,374
Syphons,		19,755
	Total Rupees,	20,41,734
Engineering and Contingencies, at 15 per cent,		3,06,266
	Grand Total Rupees,	23,48,000

The working expenses of the scheme I have proposed when fully carried out will be as follows —

Engine Establishment

1 Superintendent, at		Rupees	300	per mensem
1 Assistant,	at	„	100	do
3 Engine men,	at 20 Rs,	„	60	do
12 Firemen,	at 12 „	„	144	do
6 Coal men,	at 6 „	„	36	do
6 Coolies,	at 6 „	„	36	do
	Total per mensem,	„	676	

Fuel

Working one Engine,	8	hours per day
„ 2nd „	24	do

Total 32 hours, Engine 35 horse power effective

The consumption of Indian coal will be at the rate of 4½ lbs of coal per indicated horse power per hour

The engine will give 65 per cent of effective duty, and the total power will be 54 horses

$$\text{thus } \frac{\overset{\text{H P}}{54} \times \overset{\text{lbs}}{4.5} \times \overset{\text{hrs}}{32}}{2240} = 3.47, \text{ say } 3\tfrac{1}{2} \text{ tons per day}$$

	RS
3.5 Tons × 21 (Rs) × 30 (days) = per mensem,	2,205
Engine Establishment	676
Oil, Stores and Contingencies,	200
	3,081
Working expense at Rs 3,081 per mensem, annual cost,	36,972
The annual instalment necessary to repay Principal 23,48,000 in 30 years with Interest at 4½ per cent will be	1,44,148
or a total annual payment of Rs	1,81,120

If the Principal be repaid in 50 years, the annual payment and working expenses will amount to Rs 1,55,740

SURFACE DRAINAGE.—The improvement of the Surface Drainage of Madras is a very large subject, one requiring much thought and many levels to be taken, and probably great improvement might be made in providing new, and improving the old, channels by which the water reaches the Cooum or the sea as the case may be.

In only one case have I been able to extend my enquiries to this subject, and these refer to the Black Town sewer, of which the levels have been taken.

The area drained by this sewer is about $\frac{5}{8}$ths of a square mile, one quarter inch of rain per hour falling in this area would give about 8,000 cubic feet per minute.

The sewer is, I believe, well constructed of brickwork with a granite floor, it was built between 1850 and 1856, at a cost of about $2\frac{1}{2}$ lakhs of rupees. It extends from the sea near, and on the north of the Fort, crosses the glacis to Umpherson and Davidson's Street which it traverses, and a part of Popham's Broadway, till it reaches Old Jail Street, there it turns to the East, and along this latter street to the sea.

At the South end it has a fall in 4,180 feet from 21.7 over datum to 18.7 at the sea, 3 feet. The lower end is about the level of low water in the sea.

The other portion is 6,900 feet long, and the fall is from 21.7 to 19.0 over datum, a fall of 2.7 to near low water.

If the sewer be perfectly clean and unobstructed, it would discharge about 5,000 cubic feet per minute from each end, and would therefore be capable of carrying off a little more than $\frac{1}{4}$ inch of rainfall per hour from the area. But I am informed it requires to be cleaned out twice per annum, it is probable, therefore, that very much less than its entire capacity is available to take away storms when they occur.

Moreover, as the ends of the sewer are closed by pent stocks which require to be lifted before the contents of the sewer can escape, it may be that there is some obstruction on this account. Of course when the fall exceeds $\frac{1}{2}$ inch per hour, flooding will occur.

For improving the action of the sewer, I would advise that gully pits be constructed at every inlet, of sufficient capacity to receive and intercept the road grit, which washes into it on the occurrence of every storm. these should be cleaned out regularly.

If then the outlet to the sea be closed by proper self-acting sluices, I

think the sewer will be found to render greater service than at present in discharging rain water

I have found no road surface in this locality below the level of the sea, 5 to 7 feet above mean sea level is usual, and 5 feet is about 3 feet 6 inches above high water

China Bazaar Street is slightly higher, a few inches only, than Popham's Broadway, and causes a very slight obstruction to the flow of flood water across the glacis of the Fort to the Cooum

The existence of a mass of stagnant filth in this sewer cannot but be prejudicial to the health of the locality

PUBLIC LATRINES —In Calcutta and in Bombay also, a very large number of the poorer population resort to Public Latrines, and pay a few cowries for the accommodation In Calcutta some of these places are the property of individuals who derive very considerable emolument from them The Municipality also derive a Revenue from these Public Latrines

Where the Drainage Works are completed, these have now been altered and the Water carriage arrangement adopted with the most perfect success

In Madras there are many of these places, they occupy large spaces, and are a very decided nuisance where they exist, for this reason they are generally removed from the immediate vicinity of crowded places, and the people have some distance to travel to them

If these Public Latrines were increased in number, reduced in dimensions and the water carriage system adopted, a great improvement would be affected, and they could be placed wherever most convenient for those who use them

When the Drainage Works are completed, one or two localities may be selected in thickly populated places near to a Water Works Pipe, wherein to try the experiment of an improved latrine similar to those in use in Calcutta

The arrangement consists of a water trough passing through or under a small apartment into which the place is divided, the trough has a sloping bottom, it is filled with water from a tap at the top when prepared for use, and is emptied at the lower end, where an iron socket closed by a wooden plug is arranged in connection with the sewers After several hours use, the plug is lifted and the contents of the trough discharged, it is then re-filled with water and is again ready for use. At a cost of

Rs 2,400, a covered place to accommodate 20 persons may be constructed, exclusive of the land

DOCUMENTS ACCOMPANYING THIS REPORT —A* Level Book, accompanies this Report containing values of Bench-marks which have been established in various points throughout the town, these Bench-marks are blue whinstone posts numbered 1 to 122 The level of the squared tops is the level taken, and they are all referred to a datum 20 feet below mean sea level

In taking these Bench-marks surface levels were taken also at 200 feet apart, in every street and road These levels are written in blue ink on the Plans, but are there made to indicate the height above mean sea level

The Revenue Survey* Plans at a scale of 100 feet to the inch, have been found generally very correct, and are adopted as the basis of the scheme, on these I have laid down the line and levels for every sewer, the gradient and direction, as well as the height above datum at the different junction of the sewers, are all shown on these plans

*Plans of the Streets and Working Sections of the same are also prepared, on these the position and inclination of the sewers is shown

These Plans and Sections are given for the whole area to be drained They have been carefully checked and may, I believe, be considered as strictly accurate Drawings of the Section of Sewers, Manholes, Syphons, Pumping Station, and Sea end of outfall sewer, with an index map to the various blocks of the Revenue Survey are also prepared

The *Estimate book shows the name and number of the streets in the various divisions, corresponding with those on the Revenue Survey It gives the length, average depth, and inclination of each street sewer, the street number into which it discharges, the number of lamp holes and manholes, also the estimate for any special work, and for compensation or damage to property, and the total cost of each division drainage A* list of the streets in the various divisions, numerically and alphabetically arranged, has also been prepared

As an Engineer, it is no part of my duty to compare mortuary results, but it is no small satisfaction to be able to point to cases where lives are saved and sickness prevented

The following is taken from the Administration Report of the Calcutta

* Not republished with this Article

Municipality for 1873-74, as the total deaths occurring in that city during previous years —

1865,	23,242
1866,	20,283
1867,	12,097
1868,	13,733
1869,	12,795
1870,	10,102
1871,	10,300
1872,	11,825
1873,	11,557

Calcutta, however, is far from being complete in its Sanitary arrangements The water supply is generally distributed, but at least one-half of the community still have little or no benefit from the drainage works, all the more expensive portions are completed, but the less expensive pipe system which will make these available to the great mass of the poor native population still remains to be done, and during the present year I believe the works are suspended, Calcutta therefore even now is not in the favorable position, it is to be hoped it will be when the works are completed In 1869, the Water and Drainage works were first brought into operation, and a marked change is at once visible

But tables of mortality in this form entirely fail to convey the full value of a life saved, it also means *sickness prevented*

Medical Staticians know that for every life saved there is a large number of cases, (28 may be taken as under the mark) of serious sickness prevented, with all their concomitants of privation and misery, and the heavier portion of this burden falls on the poor

In a community like Madras, with its 3,97,552 inhabitants, if the mortality can be reduced from 33 to 23 per 1,000, as there is no doubt whatever it may be, this would amount to no less a number than 3,970 lives, and in the proportion I have mentioned, no less than 1,14,160 cases of sickness per annum would be avoided

It would be a great mistake to suppose that the community does not pay for this, not only in the physical suffering, but in loss of money

If we take 10 years as the period which is lost by a life cut off prematurely, by preventable sickness, and its value at Rs 2 per month only,

And the cases of serious and unnecessary sickness as incapacitating

the sufferer for a period of two months from employment, we shall then have as

	RS
Value of life lost, 3,970 × 10 × 12 × 2,	= 9,52,800
and by sickness, 1,11,160 × 2 × 2,	= 4,44,640
Loss per annum, Total Rs,	13,97,440

It is not pretended that these figures are strictly accurate as applied to Madras, they are believed to be rather under, than over, the actual amount

When, therefore, it is stated that it is too poor a place to indulge in the luxuries of drainage, and water supply, let it be remembered that this is one of the penalties of filth, and that it is chiefly paid by the poor who cannot help themselves, but the rich do not escape, and when surrounded by such conditions as abound in this city, nature frequently exacts the penalty from all, rich and poor alike, who neglect or break her laws

APPENDIX

The River Cooum

12th February, 1875

The condition of the river Cooum as the chief receptacle for the surface water of Madras is of the greatest importance

The area of the city is far too large to permit of any measures for effecting its surface drainage, excepting by the ordinary means of gravitation to a lower level, and as the level of the sea is the lowest that can possibly be obtained, it is evident, that if the river Cooum can be kept down to this, it will be in the best condition for effecting the surface drainage of the city

It is, moreover, desirable for many reasons that fresh supplies of sea water should enter with the daily tidal current—the presence of a stagnant lagoon of sea water closely adjacent to the most populous part of a large city is most undesirable,—but when it is made to receive the sewage of the population for weeks and months together, as at present, it becomes a source of nuisance and danger to health The greatest benefit to the Cooum undoubtedly will be the diverting of the sewage into other channels, and to prevent entirely the contamination of its waters, and should the very necessary works of drainage be executed, still in the present condition of the bed of the River Cooum (which has for many years received the greater part of the sewage) the necessity for an improvement in its condition will only be lessened in degree, and therefore, I venture to offer for the consideration of Government, a few remarks on the subject

From a daily observation of the 'Bar' since my arrival in December last, and from information with which I have been favored by Colonel Goddard, Colonel Moberly, and others, it is apparent that no regular discharge of upland fresh water throughout the year can be expected, and it is from the tidal influence alone that any power can be obtained towards the keeping of the 'Bar' open throughout the year, and the case at once resolves itself into the question of quantity and velocity of the current, entering and issuing four times in the 24 hours.

In this view of the matter, the area of the Cooum affected by the tidal influence, and regarded as a *reservoir* for the flood water at high tide, to be discharged as the tide falls, is an important feature The river when in flood, as during October last, scoured out the entire channel through the bridge, and a clean channel was left, this was the result of an enormous body of water moving at a high velocity

As the quantity diminishes at the cessation of the rains, the water of the flood tide gradually finds its way in, and it becomes a contest between the loose sand thrown up by the surf at the mouth of the river, and the entering and issuing tidal water, as this process goes on during the North Eastern monsoon current, the river is forced towards the southern end of the bridge, where there is a short groyne, and the drift sand occupies $\frac{4}{5}$ths of the waterway of the bridge, leaving a narrow channel only, this channel is kept open for several months by the scouring action of the tidal water in passing to and from the *reservoir* of the Cooum

As the river succeeds in forcing for itself a channel through the enormous quantity of loose shifting sand for several months, it may, I think be expected, that if some comparatively small means of assistance were afforded, it would remain permanently open

Those who have known the river before the rough groyne of granite boulders above alluded to was placed on the sea side of the bridge at its southern end, will be able to say how far or for what period the closing of the 'Bar' has been protracted

My observations during the past two months have shown that the outlet of the channel into the sea shifts towards the north A quantity of sand accumulates on the 'Bar' side at the head of the groyne, and gradually increases in extent, causing the opposite or north side of the channel to scour away the sand by the action of the waves which break on its face during flood tide, and carrying the sand nearer to the bridge, where a very considerable eddy is formed, and a quantity of sand is piled up at the back of the shoal first formed as above, as this action proceeds, the northern side of the channe lbecomes more and more exposed to the action of the waves, and the silting up of the channel is more and more rapid, until the time when the projecting shoal on the south side will overlap the northern side of the channel completely (it now extends to a point opposite the seventh arch from the southern end of the bridge) and will soon completely overlap the channel, in this condition of things the

waves (which break nearly parallel to the shore) will commence to cut the point of the shoal itself and drive it bodily in towards the bridge, and the 'Bar' will then at once be closed

I am of opinion that if a channel of suitable width be formed by the construction of groynes on both sides, and the entering and issuing water be confined to this channel during the dry season, that a quantity of water moving at sufficient velocity will be obtained to keep the channel open throughout the year, by the scouring action of the tidal water alone

I have roughly estimated the quantity of water which the river Cooum will contain between the South Beach and Harris' Bridge

The ordinary rise of the tide I learn is about three feet, for purposes of calculation I have taken 2 feet 6 inches as spread over the area of the Cooum between the above points, and I find the quantity to be about $16\frac{1}{4}$ millions of cubic feet which must enter through the channel at the 'Bar' in 6 hours, this quantity in a channel having a sectional area of 300 square feet, would give an average velocity of $2\frac{1}{2}$ feet per second Of course this velocity is not uniform, it is greatest about half tide of both flood and ebb, and at extreme high or low water the velocity for a brief period is *nil*, but for a very considerable portion of the six hours the velocity will be much higher, from four to five feet per second, and I consider quite sufficient to keep the channel with a capacity, such as I have mentioned, open, if the loose sand at the mouth be so far confined and controlled as to admit of the scouring action of the water being concentrated on its sectional area only, and in a direction at right angles to the general shore line

I have repeatedly observed the water entering with a velocity at the surface of four feet per second (and the channel I take to be about the size I have indicated) under the present condition of things, but the mass of sand it has to contend with, on both sides, along its whole length, is too great to be overcome by the small stream opposed to it

I am unable to say whether the waterway of the bridge is sufficiently ample to admit of 50 feet out of its 500 feet, to be appropriated to the construction of a groyne on the north side of the channel, but judging from the other bridges higher up, where the waterway is very considerably less, I should think 50 feet might be spared, in that case I should appropriate the third arch (from the south end of the bridge) to the construction of the groyne which with the existing one on the south side

should be extended about 200 feet further seaward, and to a depth which experience has proved to be the lowest point of scour under the bridge

Should it be inadmissible to construct a groyne in that position, then an independent opening further to the north would be necessary at a considerable increase of expense

The river in its shoal portion should be deepened so as to be from one to two feet of depth at low water

It would also be necessary on the approach of the monsoon season to keep the sand at the Bar down to a level which would easily admit of the flood water topping and scouring it away, so as to avoid any undue strain on the permanent channel

The upper reaches of the river may be immensely improved by training walls at intervals, to confine the stream during the dry season to a defined channel, the general bed being levelled, and it is I believe sufficiently high for grass to grow upon, not only would the general appearance of the river then be improved, but its discharging power would I consider be improved also

MEMORANDUM

April 3rd, 1875

Since the above was written the South-west winds and current have fairly set in, and a body of sand from the South has accumulated at the end of the groyne, about 100 feet in width measured seaward

It has also advanced towards the North, and the Cooum up to a few days ago has continued its struggle for existence A week since the sea end of the channel had moved northward about 400 feet from where I first observed it, and in this process an enormous mass of sand had been cut away from the land side of the channel Suddenly, about 4 days ago a tongue of sand about 250 feet in length shot forward from the growing bank, and the channel was forced into a position about paralled with the shore line, the surf breaking over this sand has now closed the channel, and the Cooum will remain a stagnant pool till the middle of October

The view I took two months ago of this subject is confirmed by what I have since observed

W C

No CC

DREDGERS AND DREDGING

[*Vide* Plates XXXV to XXXIX]

By Mr. J W Barns, *M Inst C.E and F R G.S, Supdt, Canal Irrigation, Bahawalpur State*

The utter inapplicability of any previously known type of dredger for fulfilling the several conditions essential to successful canal clearance has led up to this invention, it is possible there are defects even in it, and that improvements may yet be made which will still further simplify and lessen the cost of the process

Nevertheless, as far as at present worked out, the invention promises to effect a great revolution in this class of work, for there is not a canal or dock in the whole world where, as a labor saving machine, it cannot with advantage be used

Cheap as is labor in India, the author believes that dredging by the system proposed can be accomplished, so as to compete successfully with it, because, as the mode of working is so simplified, and as most of the operations are, so to say, self-acting, what has to be done by manual labor, can be done with a minimum number of hands

For excavating soil from canals, the space within which a dredger has to work is limited, the spoil to be removed is very often some feet in height above the surface level of water in which the vessel intended to dredge, floats, so that she has to be designed, so as to be able to eat into, and clear away, a sandbank ahead of her that may be as high as, or even many feet higher in level than, her own deck, and therefore high and dry, and as the bed of many canals is often not more than three feet below

the level of the lowest known fall of a river, her immersion (if she is intended to work throughout the year) must be limited to a draft not exceeding $2\frac{1}{2}$ feet

Lastly, after excavating the spoil, the work demanded from a canal dredger is but half done, it being necessary, in order that the operation may be complete, that the spoil be simultaneously deposited, not only as far in from the edge of the canal bank as possible, but also that it be delivered at a minimum vertical height above the canal bed of 20 feet

The invention embraces two distinct methods of accomplishing dredging work, so as to fulfil all the above requirements in the most efficient and economical way, each of these is described hereafter

Its great novelty consists in a hull of a peculiar shape, and also of a mode of working, *vide Plates* XXXV, XXXVII and XXXVIII, whereby the dredging is not only capable of being carried on without intermission, but, paradoxical as it may seem, whether (according to the size of dredger employed) the breadth to be operated on be 25 or 100 feet, there is never any space to be bridged over between the side of vessel, where the spoil leaves it, and the edge of the bank in from which the spoil has eventually to be delivered, and thus, the whole length of the overhanging and projecting shoot or pipe is utilized in conveying the spoil excavated a distance in from the edge of the bank corresponding with the length of the projecting shoot or delivery pipe

The shape of the hull is such as to offer little resistance to the water when moving from place to place, and it is intended that she should be propelled by her own engine power, and be fitted with either twin screws or hydraulic propulsion machinery

It gives the largest bearing surface possible just at that point where the strain caused by a projecting shoot or discharge pipe is greatest, and thus affords the means of efficiently supporting a shoot or pipe of extreme dimensions both as regards its length and sectional area, *2ndly*, as the distance in from the canal bank on which the spoil has to be deposited, is dependent on the height of the inner end of the shoot underneath the tumblers, it enables the shoot (according to the size of the dredger) to be placed at a height far exceeding that which has ever yet been attempted, without incurring the danger of making the vessel top-heavy or careen, *lastly*, as the number of units of work to be got out of the engine employed is limited, both by the safe limit of height of discharging

end of shoot, and also by that of its length, it follows that, if, by adopting a more suitable form of hull that admits of an improved mode of working it, both height of delivery and distance of removal of spoil in from the edge of the bank can be increased, so likewise can the number of units of work, within a given space of time, be increased also

Both the dimensions of projecting shoots carried by dredgers of ordinary type, and also the height to which such shoots can be supported, have, hitherto, necessarily been considerably limited, even in dredgers of the largest class, which seldom exceed 25 feet beam, but by distributing the superficial floating area of an ordinary 25 feet beam dredger over a hull of the shape invented, its beam can be 50 feet at the point where so much breadth is needed

Both the shape of hull and the system of working it, is common to both methods

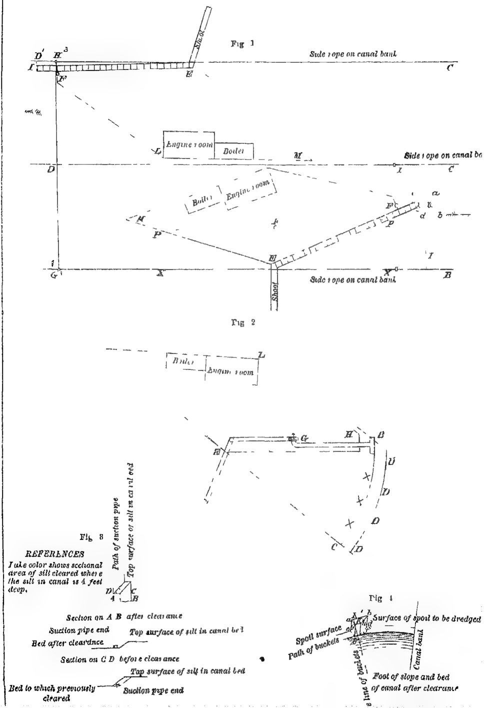
Dredgers of this type can be used as well for excavating an entirely new canal of any breadth from 25 to 200 feet, as for clearing the spoil or silt that may have accumulated in a canal that may have been already made, the only postulate being that there shall be at least six inches greater depth of water in the river or lake with which the canal or dock, which is being excavated, is connected, than the draft of the vessel employed

In Indian canal clearance, the great object is to have a dredger capable of carrying as large an engine power as possible, with a minimum draft of water and ability to support as long a shoot as possible, the new type of dredger, (*Plate* XXXV, *Figs* 1 and 2,) with an extreme beam of from two to four feet less than the least bottom breadth of the canal in which it has to be worked, fulfils the above conditions to the highest degree possible, such a dredger would of course be able to clear the whole breadth of canal offhand, at one operation, commencing at the head of the canal and working in from the river as far as dredging may be necessary or desirable, there may be cases where, owing to strength of current or other causes, it would be preferable to commence dredging, against the current, or with the dredger's head up-stream instead of down-stream, in such a case the dredger would be dropped down the canal "stern foremost," to the point where work is intended to be commenced, and, with her head up-stream, would work her way back to the river, clearing the whole breadth of the canal in her progress

In the exceptional case of a dredger being needed to clear a canal of

DREDGERS AND DREDGING

Scale 18 feet = 1 inch



200 or even 250 feet bottom breadth, there must be a limit of course beyond which it would not be proper to increase the horse power, and which would also place a limit on the floatage area necessary, and consequently the extreme breadth of dredger, so desirable up to a certain limit, would then be superfluous, therefore whilst, as a general rule, there is a great advantage in having the hull at centre of as large a beam as possible, there are limits beyond which its dimensions should be decided with reference to the special locality in which the dredger is required

In fact, although, for general purposes, the shape of hull as herein designed, seems to meet all ordinary requirements, there is no real necessity that it should be strictly followed, it is susceptible of numerous variations without necessarily departing from the principle on which the new system of dredging herein described is based

The exterior form of that part of the hull opposite the two sides which support the shoot can be designed at pleasure of any dimensions or shape that will enable the conditions dependent on required draft, least resistance in moving through water, power of engines, and length and height of shoot to be the best fulfilled, where the bucket ladder or suction tube is in the centre of the vessel, the two pivoting angles would of course be made alike

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Description of the Bucket Dredger and of the mode of working the Hull

So far as dredging and lifting the material by buckets is concerned, no improvement on the old system has been made, but the system of appliance of the buckets by the methodical and simple mode of working that part of the hull which carries them (whereby the exact place where each bucket has to work, is so accurately and easily controlled by means of the two friction capstans) is a great improvement on ordinary methods, because, with care, it is possible to ensure each bucket being properly filled

The newly invented dredgers are designed, as before remarked, with the special object of eating into, and removing at a distance, the spoil of a bank, no matter what may be its height above the surface level of the water in which the dredger herself floats

Let us consider the new proposed mode of working under those con-

ditions, contrasting it, at the same time, with the method followed in dredgers of the old type, so as to judge of its merits

Dredgers of the old type, working under similar conditions, are dependent, for their movement whilst working, on radius lines, the adjustment of which, not being capable of being made self-acting, requires constant attention, and a certain number of men in attendance on them, and with all the care and precautions possible, it is a matter of such difficulty to cause the buckets to work in the exact spot desired as to make it really impracticable, moreover, the difficulty attending any regular mode of longitudinal dredging leaves no alternative but that of dredging crosswise In doing this, as the buckets do not, as a rule, present their mouths directly opposite to the material to be dredged, and as it has to find its way into the buckets chiefly from the side towards which the line of cutting is proceeding, the buckets often come up either empty, half, or three-quarters full, the result being that the outturn of work, under the old system seldom exceeds half of that which, but for these disadvantages, the engine could have accomplished

A system of dredging which substitutes for the precarious and haphazard style just described, one which provides for every successive bucket as it passes around the lower tumbler, always being kept pressed up against solid material directly in front of its mouth, must commend itself to all who have canal dredging in hand, or who are interested in the matter

It is only by longitudinal dredging, that is to say lengthwise, as opposed to crosswise of the canal, that the cutting action of the buckets can be the best provided for, and their filling themselves be properly secured, and it is to a thorough developement of that system of dredging that this part of the invention lays claim

The hull, in plan, is shown in *Figs* 1 and 2, *Plate* XXXV, and in plan and vertical section also in *Figs*. 1 and 2, *Plates* XXXVII and XXXVIII.

When in the act of dredging, the hull swivels or pivots upon a centre at one or other of the angles E or L (*Figs* 1 and 2, *Plate* XXXV) according as she may be fitted with a bucket ladder or suction tube either at the side or centre

At such pivoting or swiveling centre, an upright capstan actuated by a donkey engine, is fixed, around which two or three turns of a rope or chain AB or C'D' stretched tightly along the bank of the canal near-

est to the swiveling centre is taken, the ends of such ropes being securely fastened on the bank, by anchors buried in the bank, or by strong stakes

In *Fig* 1, *Plate* XXXV, ABCD may be supposed to be a canal of about the same bottom breadth as that of the dredger, or ABC′D′ a canal of about double the dredger's greatest beam

It will be evident, under the above arrangement, that when the capstan before referred to, as constituting the pivot centre, is caused to revolve, the dredger hull is moved backwards or forwards in the line or direction of the works

For cross warping, a second upright capstan is fixed any where between the pivoting angles E and L, having two or three turns of a rope XPF′P′X′ around it, the ends of such ropes being secured to swivel′ blocks which traverse freely on the longitudinal side line as shown at X, X, and passing through friction sheaves on the covering board at PP′ which sheaves are so placed that their centres are equidistant from the centre of the capstan F′, it will be evident that on motion being communicated to this capstan F′, as the distance PX decreases, by so much exactly will that of P′X′ increase, and *vice versâ*, and thus, by aid of these two capstans, it will be evident that the projecting point of the bucket ladder I, *Fig* 1, or of that of the suction tube E, *Fig* 2, can be so directed as to work in any desired position or direction whatever, within the limits of any canal, or place, of a bottom breadth slightly in excess of that of the extreme breadth of the dredger hull

Should there be any Engineer however sufficiently wedded to the old system of radius warping barrels as to prefer it to the present method, in ordering a dredger of the new type, such warping barrels can be fitted without prejudice to the other important points of the invention

In *Fig* 1, *Plates* XXXV and XXXVIII, the bucket ladder is placed on one side of the vessel, and in *Figs* 1 and 2, *Plate* XXXVII, the bucket ladder is placed within a well, through the vessel's centre, *vide* letters LL, *Fig.* 1, and MM, *Fig* 2, *Plate* XXXVII This latter arrangement offers no novelty, it having been in use years since on the river Clyde, and may still be seen in the Suez Canal dredgers, and, where the height of lift, and the distance in from the edge of the bank on to which it is desired to deliver the spoil, are not special objects, there is an advantage in the arrangement, but where the object is to secure the greatest height of lift as well as the most distant point of delivery of spoil in from the

edge of the high bank that is possible, it will be obvious that this ca best be secured by placing the bucket ladder on the outside of that side the hull nearest to the bank on to which the spoil has to be lodged

For instance, supposing the height of the upper tumbler in eith case to be fixed, then, as regards the shoot discharging from the cer tral bucket ladder, it loses a height of final delivery of the spoil equ to what is necessary to secure the flow of the dredgings by gravitatio over a space equal to half the vessels extreme breadth, which, in one c moderate dimensions would be 25 feet, and with the slope of shoot have proposed, viz, 1 in 4, the head so lost, allowing the centre of th tumblers of the side bucket ladder to be 8 feet in from the outer edge c the vessel's side, would be upwards of 4 feet

This question, like many other similar details, can only be decide after full consideration of every circumstance and condition connected wit the duty required, and more especially a knowledge of the locality wher a dredger is wanted to work, also of the height of delivery and lead c the dredgings that may be desired or insisted on

Both the bucket ladder and the suction tube, whether at the side as i *Figs* 1 and 2, *Plate* XXXV, or in the centre as at *Figs* 1 and 2, *Plat* XXXVII, are made so as to project a certain number of feet beyond th vessels fore foot, as shown in *Fig* 5, *Plate* XXXVI

The necessity of this needs explanation

If at the time the canal is being cleared, there is not sufficient water i the canal to admit of the dredger floating over the place to be dredged, i will be evident by inspection of *Fig* 5, *Plate* XXXVI, (which though drawn for illustration of the suction type, applies as far as this point i concerned to both systems,) that the distance which the dredger will b able to dredge longitudinally or in the line of canal, will be limited to the length that the bucket ladder projects beyond the fore foot of the vessel's hull, which, in present illustration, is supposed to be 10 feet, as is shown also in *Fig* 1, *Plate* XXXV, where the path of buckets along line IK is of that length, for referring to *Fig* 5, *Plate* XXXVI, when point H wil have advanced to F and that of F to F′, or, as in plan, *Fig* 1, *Plate* XXXV., when the cutting buckets have advanced from I to K, the further progress of the dredger longitudinally would be arrested by the bank ahead.

By inspection of *Fig* 4, *Plate* XXXV., it will be observed that in following the path shown by letters FK, the cutting buckets actually

DREDGERS AND DREDGING

Fig 5

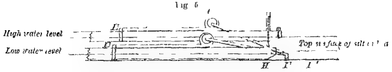


Fig 6

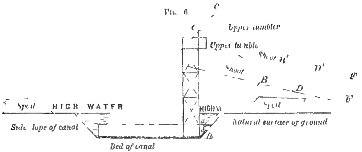
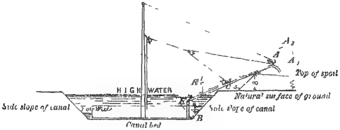
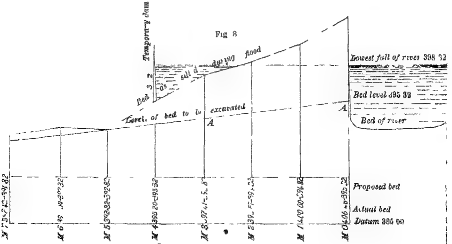


Fig 7



Scale 48 feet = 1 inch

Fig 8



Horizontal scale 2 miles = 1 inch.

Vertical scale 8 feet = 1 inch

remove a prismoidal block shown by the letters *a*, *b*, *c*, *d*, *e*, *f*, *g*, *h*, supposing the depth of silt as there represented, be four feet in depth, and that it be of a material whose natural slope is $1\frac{1}{2}$ to 1

In *Fig* 4, *Plate* XXXV, although theoretically FK′ is the line of greatest effect for the path of the buckets, practically, that shown by line FK will be found nearly as effective, and although there is no more difficulty in working through the path FK′ than in that of FK, the latter is recommended, because that path being parallel to the canal banks, only one of the friction capstans (viz, that which moves the hull longitudinally) need be set in motion during the whole time occupied in working from F to K, and in running back to commence the cutting of a fresh longitudinal prismoidal block adjoining that just previously excavated

When the vessel has sufficient water to admit of her floating over the material to be dredged, the distance to which the longitudinal prismoidal blocks can be excavated, before the dredger is run back to commence another line of prismoidal cutting can be varied at pleasure, it would seem advisable, however, that such distance should be limited by the length of the longitudinal side rope

As long as the length of the projecting shoot remains unaltered, the whole spoil excavated from the entire breadth being cleared by the dredger will be deposited in a strip parallel to canal bank four feet wide at top, and side slope about 1 to 1 As the water rises in the canal, this parallel strip will be deposited one foot further in from the canal bank for every foot of rise

Although, whether the bucket ladder is central or on one side, the dredger is proposed to be so constructed as that the portion of the hull intervening between the point of discharge from the buckets or pump, and the central pivot on which the vessel works shall, as far as possible, be employed, or adapted, to support the tube or shoot, in the one case, viz, that where the bucket ladder is on one side of the vessel, its weight and leverage, and also that of the bucket ladder, would have to be counterpoised and counteracted by the weight and position of the engines and boiler, and also with the addition of any ballast that may be necessary In the latter case, viz, that where the bucket ladder is in the centre of the vessel, in my early dredger designs prepared some years since, I fitted a shoot projecting on either side, one counterbalancing the other, discharging the dredgings only in one at a time, viz, that on the land side, or that on which the dredger for the time being pivots or is

working. In such case, the engine and boiler would have to be so pl as to counterbalance the weight of the bucket ladder only, so as to serve an even keel fore and aft

As regards the method of suspending the shoots or tubes, no nov is claimed, the large bearing surface of the hull affords ample means giving all the solidity required to the framework supporting the sl ing, buckets, bucket ladder and tumblers

On large works, or works where more than one side bucket l dredger is in use, it would be advisable to have some made right, some left handed

In *Fig* 6, *Plate* XXXVI, the dredger with side bucket ladder is sh in cross section when water is at its lowest, and also the position of s and upper tumbler at high water, here supposed to be 3 feet and 12 in depth, respectively

Up to point B, (the outer end of strut projecting from the vess E,) I have supposed the shoot to be rigid

Beyond point B the shoot is suspended by the tie CD, secured to highest point of the framing which carries the upper tumbler

There may be circumstances where it would be advisable to fold u entirely disconnect this projecting portion BDF

In order to better distribute the spoil excavated, there appear t plausible reasons for not fitting this part of the shoot at all during season when river is not in flood, and adding on lengths as the river r this plan would enable the spoil raised to be distributed with more unif ity year by year, these, however, are details, which had best be discu with reference to the locality where a dredger is required to work

Having in view the large addition to the first cost of a dredger co quent on the greatly increased strength of all the parts of the fra and bucket appendages, the larger engine power absorbed, and the e draft of water involved, in providing for excessive distance of deli in from the bank, I think it would be well first to consider whethe the economical and special purposes for which the services of a dre are called into requisition, may not be considered to have been duly full by depositing the soil, which has been dredged, on to the nearest high p of the inner edge of prior existing spoil, or on to the outer edge of cess or bern, and arranging for its removal therefrom by tip wag gravitation, or manual labor, as may be considered best

With regard to the extreme length of shoot, that shown in the Plate is 60 feet but this is not necessarily a limit, and with regard to slope of shoot, I have shown it as 1 in 4 I am aware that as compared with the slope of the Suez canal shoots that slope is excessive, but as the new type of dredger admits of the inner end of shoot being raised to an excessive height without the fear of the vessel being top-heavy therefrom, there is no reason why we should not be liberal in this matter, the additional height which enables a good slope to be given to the shoot enables its sectional area, and consequently its weight to be proportionately diminished

I have observed that in a shoot with a slope of 1 in 4, the material dredged flows freely down the shoot without the aid of water

On the Suez canal, the shoots have a very moderate slope of 1 in 20,* and the material dredged (sand) passes freely down when mixed with a quantity of water equal to half its bulk, whilst for clay, a slope of from 1 in 12 to 1 in 16 seems to have been sufficient, the clay needing only as much water added as would moisten the mass

There may be circumstances where a shoot of 60 feet length may not under any circumstances even be considered necessary, and the height of delivery required may be greater or less than here shown, of course in proportion as length of shoot can be decreased, so can height of delivery be increased, or *vice versâ* If required for canals such as we have in the Bahawalpur State, and for general work, a medium sized dredger of the size and design in *Figs* 1 and 2, *Plate* XXXV, and *Fig* 6, *Plate* XXXVI, would suit, it would work in any canal of not less bottom breadth than 52 to 54 feet, and would thoroughly excavate or clear any bottom breadth from 54 to 104 feet If wanted for a canal of less minimum bottom breadth, the maximum breadth of hull would be lessened by as many feet as the minimum breadth of canal in which dredger is intended to be worked is less than 54 feet, the outer sides of the lozenge, though maintaining the same parallel, would be proportionately lessened, and all other dimensions might remain the same

As it may often happen that the canal to be dredged exceeds in bottom breadth the extreme breadth of dredger, it is desirable to explain the method I propose for clearing such canal nevertheless

Let us suppose the lines AB and C'D', *Fig* 1, *Plate* XXXV, to be the exterior outline of a portion of a canal 104 feet bottom breadth, and

* *Vide* Professional Papers on Indian Engineering [First Series,] No CCXX

that the dredger available for its clearance has an extreme breadth of only 50 feet, and that *Fig* 8, *Plate* XXXVI, shows the longitudinal section of a portion of such canal requiring excavation or clearance

Bearing in mind that no dredger of the improved type can clear any ground or canal of a breadth which is not at least two feet or more, less than that of her own extreme breadth of beam, it is clear that the dredging of such a canal must be done in two operations

I should commence by dredging the first half breadth of such canal, as for instance ABCD, with the dredger's head down-stream, and, having cleared as far in from the river as desired, should then run her back to the river and reverse her, and if she was fitted with a side bucket ladder, I should drop her down, stern foremost, to the point up to which she had previously excavated, and having first laid down the longitudinal guiding line on the bank D″C″ should then commence dredging the remaining half breadth of the canal CC′DD′ by working with her head up-stream in the direction of DD′

If the dredger were fitted with a centre bucket ladder and second pivoting centre at L, it would be optional whether the part DD′C′C′ were excavated by commencing at DD′ or at CC′

Supposing, however, a case where the dredger has a side bucket ladder, and that there is not sufficient water in the canal to float the dredger, or that there was a probability of a fall in the river before the part CC′ DD′ was cleared, I should select a point in the canal, in from the river where, by erecting a temporary dam across the bed of the canal, I should be sure of having at least six inches more water standing against it than the greatest draft of the dredger, even when the parent stream may have fallen to its lowest zero, and thus after having cleared the first half breadth with her head down-stream, I should ensure her having sufficient water to float her for commencing the second half breadth with her head up-stream

In this instance, the proper place for such a dam would be at the end of the fourth mile, *vide Fig* 8, *Plate* XXXVI., where, by its erection there, the necessary conditions would be fulfilled

For clearance beyond that, a similar operation would have to be repeated.

Instead of running the dredger back to the river to be reversed, bays may be constructed at points along the canal, of size sufficient to admit of the dredger being turned round end for end

In the case of a dredger built for permanent duty in a canal which may be

fitted with head sluices, (which would prevent her having access to the river for the purpose of turning,) such bays would of course be indispensable.

In the aforegoing remarks regarding the maximum breadth of dredger hull admissible in any canal of a given bottom breadth, I have supposed the canal to be straight. In a canal with very sharp curves, the maximum beam possible in a straight canal would have to be curtailed proportionately with the decrease in radius of curvature, for excavating portions of the breadth in a curve, and often in excavating the first portion of the canal head in from the river, there would be an advantage in having the means of working on a pivot at the end of the vessel, say M, *Fig.* 1, *Plate* XXXV., in such case, capstan E may be movable, and cross motion would have to be effected by radius lines worked from winches.

In *Figs.* 6 and 7, *Plate* XXXVI., a conical friction roller will be observed fitted on to the lower end of the spindle of the capstan near point E., this will prevent point E from grazing the bank when the vessel is moved longitudinally. In order to give egress and ingress between the vessel and canal bank at all times, a projecting platform on a level with the vessels deck will be fitted near the angle E.

When our Indian rivers are at their lowest fall, it is essential in order that dredgers may be able to work in canals at that season, that their draft of water should be as little as possible, and that is why I fixed on $2\frac{1}{2}$ feet as a maximum limit.

It is questionable whether, in the case of dredgers of the bucket type, these can ever be turned out with a less draft than $2\frac{1}{2}$ feet when working, but, as regards those of the suction type, I see no reason why they should not be constructed with a working draft of 1 foot 9 inches or even less, the draft must however necessarily be much dependant on the height, length, and arrangement, of the shoots or discharge pipe.

There are of course numerous situations where it may be advisable to employ dredgers of this type, and where draft of water need not be considered, in such case, the size, and consequent cost, of hull may be considerably lessened, and if necessary the strength of hull be increased.

Hence, it is evident, that in ordering dredgers of this type, builders should be furnished with full particulars of every circumstance connected with the locality where they are intended to be used.

The invention is patented in England, under Specification No. 3789, dated 3rd November, 1874, and dredgers on the new principle can be man-

ufactured there, without restriction, by any one, on payment of a nominal royalty The invention not having been protected in India, is the property of the public here

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Description of the Suction Silt Ejector

The second type of dredger called the "Suction Silt Ejector," has been designed specially for the clearance and ejection of quicksand, silt or indeed any kind of material coming under the denomination of sand in a state of comminution, and liquid mud, such as is found in all Indian canals and also in most tideways, harbors and docks In India its use would more generally be confined to the clearance of a substance denominated "silt," a substance which is always in suspension in flowing water and which seems to be the universal medium in which the normal spring water level is found throughout the alluvial plains of the Punjab and Gangetic valleys

It is to that substance we owe the shifting nature of so many of our Indian rivers and also the sandbanks and bars which so seriously impede their navigation, and which often block up our best harbors, and lastly, it is the great bane of nearly all canals drawn from any river in the plains, inasmuch as the water and silt are so intimately combined and intermingled, that for every thousand measures of water, at least one measure of silt must be accepted, one-half of which invariably separates from the water and settles in some part or other of the canal, and has to be regularly or periodically removed from the bed, otherwise, so insidious is its nature, that, left undisturbed, any ordinary artificial watercourse cut through alluvial soil, no matter with what degree of perfection and skill it may have been constructed, would, in the course of a few years, become completely silted up

The almost insurmountable difficulty of excavating canals in the plains to a depth below spring water level sufficient to ensure their perennial flow, (owing to the water lying in a stratum of either quicksand or of fine micaceous silt, which being of such small specific gravity has hitherto baffled all attempts at clearing to the depth required by any known process,) is at the present moment the one great obstacle in the way of opening out a cheap class of perennial canals from our Indian rivers, owing to the heavy outlay necessary for constructing a weir across the river of supply, in order to obtain the head or depth of water wanted

For achieving this great object, to clear sandbanks obstructing navigation, whether in rivers or tidal channels or harbors, and for maintaining perennial flow in running canals by removing silt as it deposits, the "Suction Silt Ejector" is especially adapted. Like the bucket type before referred to, it is possible to clear (according to the size of dredger employed) a canal of 200 feet bottom breadth with the same facility as one of 25 feet, (no matter to what height above the level of bed silt may have been deposited,) and can convey the spoil so cleared a much further distance in from the canal bank than is possible with the bucket type.

There are certain axioms connected with this process, however, which must be thoroughly understood before the process itself will be intelligible.

The silt of the Indian rivers has a specific gravity when dry, of 1·45, when fully saturated with water, of 1·74, subjected to any velocity up to, and exceeding four to five feet per second, it becomes suspended in water, and in such state of quasi-fluidity, it is amenable to the same laws as any other fluid of similar density.

When fully saturated silt is mixed with an equal volume of water, its specific gravity is reduced to 1·38, and with half its own bulk of water, the specific gravity is 1·49.

As the velocity through the tubes of a centrifugal pump, in all but the smaller sizes, (which from their small discharging power are inapplicable to a process on such a scale as herein contemplated,) is nine feet per second and upwards, and as remarked above, as the silt of most of our Indian rivers becomes suspended in water when subject to a velocity of five feet per second and upwards, it is evident that if the end of the suction tube of a centrifugal pump be immersed in a mass of liquified silt, it can be pumped or forced to a distance under the same conditions as any other liquid of similar specific gravity, further that, as compared with water, the only difference between pumping it and pumping liquified silt would be that the latter would need more power directly proportionate to the relative specific gravities of the two substances, which in this case would be as 1·38 to 1, supposing the water incorporated with the silt to be of equal volume with it, but the ordinary form of the pump itself would need a slight modification.

The remarks on, and explanations of, the bucket dredger, and the mode and system of working the same, apply generally to the suction silt ejection dredger, and therefore need no recapitulation.

In the process of excavating, raising and delivery of the silt, there is however a great divergence from that of bucket dredging, indeed excepting in shape of hull, and the system of working it, there is nothing in common

Instead of a cumbersome and heavy projecting shoot, whose extreme point of delivery in from the edge of canal bank, we may assume as 80 feet, requiring not only its inner end to be set at a great height to admit of the spoil lifted by the buckets descending to its place of deposit by force of gravity, but demanding also a very strong framework to carry it and the shafting, and to support the weight of the bucket ladder and upper tumbler on which the buckets revolve, we have in place thereof simply a centrifugal or other pump with its suction and discharge pipe, the latter (supported by a mast or pair of shears) projecting but a comparatively short distance beyond the vessel's side, with the capability, when its outer end is at a vertical height of only 26 feet above the canal bed, of depositing the material raised a distance of 328 feet in from the edge of the bank, and the option of still further increasing that distance by merely raising the outer end of the discharge pipe, *vide Fig* 2, *Plate* XXXV, and *Figs* 5 and 7, *Plate* XXXVI

The simple and ingenious method of suspending the projecting discharge pipe, and that of fitting it with a universal joint at E, is the invention of my Co-patentees, Messrs Simons and Brown

The economy of power involved by Messrs Simons and Co's universal joint will be evident, seeing that were the projecting discharge pipe rigid, if of the height shown in *Fig* 7, *Plate* XXXVI, its extremity being a horizontal distance of 48 feet beyond the vessel's side, at the time of high water—its end A would be in the position A^2, which would necessitate a lift through one-third more vertical height than is wanted, whereas, by means of the universal joint, end A can always be kept at the same vertical height above the bed by lowering it gradually as the water rose, or lifting it when the river fell.

There is another advantage besides in this arrangement, and that is that when moving from one part of the river to another, the projecting end can be triced up clear of the river bank or of boats or vessels passed on the way

In the section, *Fig* 7, *Plate* XXXVI, E′A′ shows the inclination and position of the projecting pipe when there is 12 feet of water in the canal.

In this section, the discharge pipe is shown projecting 48 feet horizon-

tally beyond the side of the vessel with its discharging end A 26 feet above the level of canal bed This shows a type, but in no wise implies a limit in either case, it merely foreshadows the large margin to which it is possible to increase either of the above dimensions in situations where it may be deemed desirable to do so

Silt is such an insinuating material, (and under pressure it would be more so,) that I fear whether in practise it would be possible to manipulate a discharge pipe with such a joint, however promising it may appear in theory, if however, it is attempted, surprise must not be felt if disappointment ensues

I see no reason, however, why an ordinary coupling joint admitting movement of projecting arm through a vertical plane should not answer

Experience on the Suez canal has shown that the sands there met with when intermixed with half their volume of water, are capable of descending by gravitation, a slope equal to 1 in 25, and, as the discharge end of projecting tube in design is 12 feet above level of ground surface, it will be evident from the above hypothesis, that when once rasied to the point A, the material would flow off to a point 300 feet distance.

I have carefully examined the sand of the Egyptian Desert, and found it (technically speaking) sharper than the silt of our Indian rivers, and deficient in mica to which Indian silt owes its low specific gravity, consequently, as compared one with the other, (fall and volume being the same,) the semi-fluid silt of lesser specific gravity would flow faster than that of greater density, and, therefore, in order to attain an equal speed of flow with both materials, the lighter of the two would need less slope, and would consequently transport itself to so much further distance

The silt suction process admits of both longitudinal and cross dredging as I will explain

For cross dredging, the end of suction tube terminates in a double head *vide* plan, *Fig.* 2, *Plate* XXXV, and elevation at *Fig* 5, *Plate* XXXVI, and the same on enlarged scale in *Figs* 5 and 6, *Plate* XXXVII

The suction ends of this double head would of course be used alternately; that is to say, when the vessel is working, for instance from C towards B, *Fig* 2, *Plate* XXXV, the pump would be supplied from the left side suction end, and *vice versâ*, a throttle valve is fitted within each suction end, in such a manner that by a simple movement whilst one of the valves is being closed the other would be opening, and *vice versâ*

This process of dredging is very simple, and will be understood at once by inspection of the Plates

As soon as the dredger has cleared through the circular arc from C to B, *Fig* 2, *Plate* XXXV, and the next arc beyond has to be commenced, the end of suction pipe will be raised, the vessel propelled forward as necessary, and the suction pipe end be again lowered

Their own weight will sink the ends into the silt, during the interval occupied by the ends working down through the silt, to the bed level, both throttle valves should be kept half open, and when the cross dredging commences, if working from left to right, the left valve would be closed, and the right valve be kept open, and *vice versâ*

The principle on which the feed of the suction pipe end depends is that of undermining, as for example is sketched in *Fig* 5, *Plate* XXXVII, in which, at point F, a revolving agitator or rake is placed, which stirs up and commingles the sand and water preparatory to its being sucked in at the end of the suction tube

This agitator is kept in motion by gearing connected with the axis of the centrifugal fan

A most valuable suggestion has been made by Mr Molesworth, M Inst C E., on the subject, of which the writer has a high opinion That gentleman proposes to undermine the silt by jets of water acting on it under pressure, and so dispense with the mechanical agitator entirely, and consequently the wear and tear inseparable from gearing placed in such a position, attention having been drawn to both methods, it will be open to experiment to determine which is the most suitable

Now with regard to the form to be given to the end of the suction tube

Silt in a state of repose assumes a slope of $1\frac{1}{2}$ to 1 In undermining the silt, this is the angle which it will continually be trying to arrive at The disturbance occasioned by the undermining would practically never allow the silt which is being acted on, and which is immediately in front of the end of suction tube that may at the time being, be working, to assume that angle, the end of the tube, however, has been designed of a rectangular shape, and so as to present itself to the silt at the lowest possible angle as shown in vertical section, *Fig*. 5, *Plate* XXXVII

The main is here supposed to be 18 inches diameter, and the suction end 18 inches square, the vertical height of upper lip of suction above the horizontal plane of lower lip F being about 10 inches

With regard to the line of silt immediately in advance of that portion of any arc that may have been either wholly or partially cleared, viz, that for instance marked × × × in *Fig* 2, *Plate* XXXV, it is supposed that in working from C towards B, the line marked × × is really the foot of slope of the silt of which DDD is the surface

Fig 3, *Plate* XXXV, shows the plan of a canal supposed to be silted four feet deep, and on it is shown the path of the suction pipe in the act of clearing any circular arc through soil, whose natural slope is $1\frac{1}{2}$ to 1

DC shows the cross section immediately in front of the suction tube end, and AB the cross section in rear of the suction tube The end of the suction tube being supposed to be $1\frac{1}{2}$ feet square, the portion colored lake is the area excavated per each running foot of passage of suction tube through the circular arc

Whatever may be the shape of end of suction tube adopted, there is one great point to be aimed at, viz, to keep it as much as possible well entered into the silt which is being attacked, the plan here shown seems theoretically good, doubtless experience will suggest improvements, and it would seem advisable that spare ends of different shapes should be sent with any dredgers of this type first ordered, so that trial may be made as to which is the most effective

Instead of a double headed suction end, a single curved suction end may if preferred be used, with this difference that the dredging could not so well be done crosswise as longitudinally, and on this point the same remarks as on bucket dredging apply equally to this

In *Fig* 5, *Plate* XXXVI, the extreme end of suction tube projects 10 feet beyond fore-foot of the vessel, the only inconvenience apparent from this arrangement is the weight of the tube when charged with silt and water I propose to counterbalance this by running back a trussed lever from G towards E, which would enable the suction tube GF to be raised or lowered with a minimum expenditure of power, and at the same time instantaneously

Every new Invention that comes before the world is liable to criticism, and this I rather court than otherwise, and I trust that such of my friends as are interested in dredging, and who may take the trouble to wade through this somewhat lengthy description, will criticise the same in a friendly spirit, and that they will favor me with any suggestions that may now occur to them, or that may hereafter occur where any of them have

an opportunity of seeing any of these dredgers at work, and should there be any point requiring elucidation which is either not touched on in this description, or which is not sufficiently clear and intelligible, it will be a pleasure to the author to discuss the subject with any Engineer or other person interested in dredging.

Provisional Specification, dated 3rd November, 1874

This invention relates to, and consists in a new or improved form and arrangement of the hull and machinery, and of the discharging shoot or pipe of dredgers for excavating and deepening channels, canals, rivers, basins, docks, or other similar works, and for depositing the dredged materials on the adjacent banks or wharfs, or into barges or other receptacles, and also to a new or improved system or mode of working the dredgers whilst performing these operations

The hull of the dredger is in plan of a double triangular form, that is to say, it is formed of two triangular shaped figures having their bases united

When in operation, the hull of the dredger is attached at one side or end of the line whereat the bases of the triangles meet to a point, on which it is capable of moving as on a pivot or centre, so that the outer ends or points of the triangular figures and the bucket ladder or suction pipe are moved in a curved arc across the face of the work which is being excavated or dredged The dredger is drawn across the face of the work by ropes or chains stretched across the work approximately in the line which forms the chord of the arc described by the end of the bucket ladder or suction pipe The rope or chain, or ropes or chains, have their extremities fixed or anchored on the banks, and it or they is or are turned one or more times round a capstan or other similar purchase, preferably placed at or near the fore part of the vessel, so that when motion is communicated to the capstan, the fore part of the dredger is hauled to any side of the work by winding on the chain or rope The position, however, of the said capstan is not confined to the fore part of the vessel, as it may be placed at any other suitable point thereon, and instead of one capstan two or more such capstans may be used, and operated either from the engine direct, or from a small donkey engine provided for that purpose

The dredger is moved in the direction of the length of the channel, canal, or other work by another rope or chain fixed at its two extremities

on the land or near the bank in a direction parallel to the length of the channel or canal being excavated, that portion of the chain or rope intermediate between the fixed extremities being passed one or more times round a capstan or other suitable purchase situate on the point or pivot whereon the dredger is centered

The bucket ladder may either pass through a central well in the hull, or it may be situated at one side, or bucket ladders may be placed at two or more sides, and the shoot or tube into which the dredgings are delivered by the buckets is made to project in the direction of the land or bank, or towards any suitable receptacle into which it is desired to deposit the dredgings, the dredger being so constructed, that the portion of the hull intervening between the point of discharge from the buckets and the point whereon the dredger is centered is employed to support the tube or shoot

In some cases the dredger is provided with a receptacle, into which the dredgings fall from the shoot In this receptacle an agitator may be placed which mixes the dredgings with water, in which state or condition they are forced through a line of pipes, and deposited on to, or in from the banks, adjoining, or at the sides of the work, or into receptacles by the action of centrifugal or other pumps

In combination with the dredger herein before described, any arrangement of apparatus other than the usual bucket ladder which is suitable to the nature of the soil to be dredged may be employed. Instead of forming the hull of the dredger of two triangles, as herein-before described, it may consist of one such triangle in form, or it may be made angular on two sides and curved on the third side without interfering with the efficient working thereof

In lieu of anchoring each end of the hauling or warping chain or rope, or chains or ropes, by which the dredger is moved through an arc from one side of the work to the other, as herein-before described, bights or loops may be formed on the extremities of the said chain or rope, or chains or ropes, through which guide ropes or chains stretched tightly along the banks of the work pass, and by this means the necessity of shifting the anchorage of the aforesaid hauling chain or rope, or chains or ropes, when the dredger is moved forward is obviated

The steam after it has passed from the engines which drive the ejecting pumps, when such are used, may be conducted through, and caused to actuate the engines which drive the dredging buckets

Specification, dated 1st May, 1875

The invention relates to and consists in a new or improved form and arrangement of the hull and machinery, and of the discharging shoot or pipe of dredgers for excavating and deepening channels, canals, rivers, basins, docks, or other similar works, and for depositing the dredged materials on the adjacent banks or wharves, or into barges or other receptacles, and also to a new or improved system or mode of working the dredger whilst performing these operations

The hull of our improved dredger is in plan of a double triangular form, that is to say, it is composed of two triangular shaped figures having their bases united

When in operation, the hull of the dredger is attached at one side or end of the line whereat the bases of the triangles, meet to a point on which it is capable of moving as on a pivot or centre, so that the outer ends or apices of the triangular figures and the bucket ladder or suction pipe, according to the character of the dredging mechanism is moved in a curved arc across the face of the work which is being excavated or dredged The dredger is drawn across the face of the work which is being excavated or dredged by one or more ropes or chains stretched across the channel, canal, or river, in a line forming a chord of the arc described by the outer end of the bucket ladder or suction pipe The said rope or chain or ropes or chains, is or are at one end fixed or anchored to the banks, and it (or they) is (or are) turned one or more times round a capstan or other similar purchase preferably placed at or near the fore part of the vessel, so that when motion is communicated to the capstan, the fore part of the dredger is hauled to either side of the work by winding on the chain or rope The position, however, of the said capstan is not confined to the fore part of the vessel, as it may be placed at any other suitable point thereon, and instead of one capstan, two or more such capstans may be used and operated either from the engine direct, or from a donkey engine provided for that purpose.

In lieu of anchoring each end of the hauling chain or rope or chains or ropes by which the dredger is moved from side to side of the channel as herein-before described, bights or loops may be formed on the extremities of the said chain or rope or chains or ropes, and these are thereby coupled to the guide ropes or chains stretched tightly along the banks of the work, and by this means the necessity of shifting the anchorage of the aforesaid

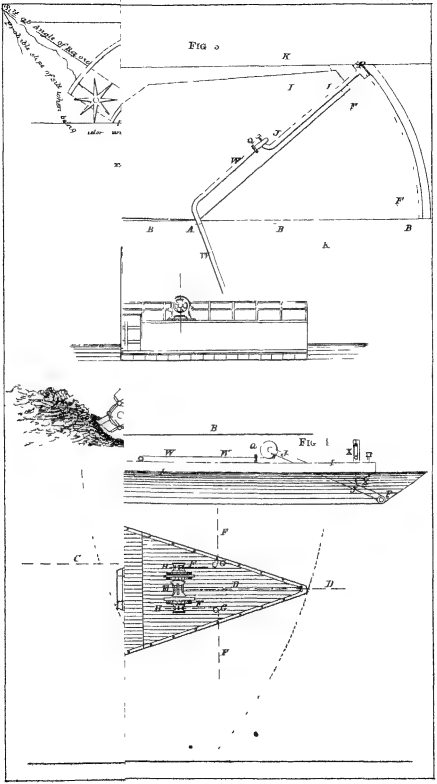


FIG 1

the ends thereof are so made to describe an arc as indicated by the dotted lines on *Fig* 2, *Plate* XXXVII, whereby the dredging buckets or suction apparatus is caused to act upon the whole breadth of the work, as shown more clearly at *Fig* 3, *Plate* XXXVII, which is a diagram plan of a dredger hull I fitted with a suction pipe J, and floating between the banks K of a river or canal, *Fig* 4, *Plate* XXXVII being an elevation corresponding to *Fig* 3, *Plate* XXXVII The hull I is centred or pivoted at the point A, and by hauling on the ropes or chains last described, the ends of the dredger are warped across the stream or channel, and the suction pipe end caused to describe the arc shown at *Fig* 3

Instead of employing two ropes or chains F for each side of the dredger, one such rope or chain may be used at each end of the hull, and passed around a single upright or horizontal capstan or winch situated thereon, and instead of anchoring or otherwise fixing the extremities of such ropes or chains to the banks of the works, they may be secured to guide ropes or chains extending along the banks, preferably by means of an eye, bight, or sheave, and by this means the necessity of shifting the anchorage of the cross warping ropes or chains at each forward or backward movement of the dredger is obviated, as the loop or bight slides along the guide ropes or chains as the position of the dredger is advanced

As it is necessary that the herein-before described cross hauling ropes or chains should be in a constant state of tension, so as to keep the dredger in its position relatively with the banks of the river, channel, or canal being excavated, the said ropes or chains are preferably attached to their anchorages on the banks or to the guide ropes or chains last referred to by means of blocks and tackle, so that as the dredger hull rises or falls with the water level in obedience to tidal or other influences, the cross hauling ropes or chains may be lengthened or shortened to suit the height of the water line

The bucket ladder L, *Fig* 1, *Plate* XXXVII, or the suction pipe employed in lieu thereof, may be suspended in a well M, *Fig* 2, formed in the ordinary manner at the central part of the dredger and extending towards one end of the hull or otherwise The bucket ladder or suction pipe may be situated at one side of the hull, as shown upon *Plate* XXXVIII It is preferred to place the engines and boiler for actuating the bucket ladder or suction pipe at one side of the hull, as shown at *Fig* 2, *Plate* XXXVII, so as to counterbalance the weight of the shoot or tube into

which the dredgings are discharged from the buckets or suction pipe The said shoot or tube (not shown on the Plates) is of the ordinary construction, and is made to project towards the bank from the side of the hull opposite to that whereat the engines and boiler are situated, the shoot or pipe being stayed or supported on the hull, and allowed to overhang or project over the bank so as to discharge the dredgings at a sufficient distance in from the channel, or under another arrangement the dredgings may be discharged into any receptacle provided to receive them In some instances, such a receptacle is placed on the hull itself, and the dredgings discharged thereinto from the buckets, after which they are mixed with water by an agitator or equivalent means, and are thereafter forced in a liquified state, by centrifugal or other pumps through a range of pipes Z to the point of discharge upon the banks

Under another arrangement of the dredging apparatus, illustrated at *Figs* 3 and 4, *Plate* XXXVII, the hull I is pivoted upon and traversed backwards and forwards by means of the guide rope or chain B stretched tightly along the bank K, and cross ropes or chains F are employed to warp the ends of the hull and end P of a suction pipe J across the face of the work A centrifugal pump Q is situated upon the hull I, and agitators are arranged in the suction pipe end P, as more particularly shown at *Figs* 5 and 6, *Plate* XXXVII *Fig* 5 is a vertical section on an enlarged scale of the suction pipe end P, at the line *a*, *b*, *Fig* 6, the dotted lines marked J, *Fig* 5, representing the position of the main suction pipe J

A rectangular compartment R is bolted upon each end of the portion P, within which are agitators S composed of a series of arms or stirrers, arranged at intervals around an axis U supported in bearings from the sides of the compartment R, and actuated from the hull I by means of a chain and chain pulley or other suitable gearing or mechanism While the pipe end P is progressing across the face of the work, the leading agitator is caused to revolve and so stir up the silt, sand, or other soil, which becomes mixed with surrounding water, and is drawn up the main suction pipe J by the action of the centrifugal pump Q The suction pipe end P is provided with throttle valves V, V^1, situated behind the agitators, and arranged so, that when the end P is moved in the direction of *x*, *Figs* 5 and 6, the valve V is open, while the valve V^1 remains closed, whereas when the end P if moved towards *y* the valve V^1 is opened, and the

valve V closed, thus it will be seen that the dredgings are sucked through only one end at a time, that is to say, through the opening that leads or is nearest to the bank, towards which the dredger is being drawn across the face of the work The suction pipe J is attached by a movable joint at or near the centrifugal pump Q, and may be raised and lowered like an ordinary bucket ladder by tackle X situated near the bows of the dredger After passing through the pump Q, the liquified dredgings are forced through a range of pipes W, and discharged upon the bank K or into any suitable receptacle

In dredging with the herein-before described suction pipe J, jets of water may be used in lieu of the agitators S, and as the pipe end P while in operation is sunk beneath the level of the river or canal bed, the jets of water are forced into and undermine the soil, which then falls in, becomes mixed with the surrounding water, and is drawn up through the suction main as herein-before described The advantages of thus using jets of water as an undermining or loosening agent are, that thereby the agitators and mechanism for operating the same are supplanted by means less costly and less liable to get out of order When one dredging operation has been performed by moving the hull towards one bank of the channel or canal, the end P of the pipe J is raised, and the hull advanced the necessary distance, after which the end P is again lowered into the material, and the hull moved through an arc so as to dredge towards the opposite bank

The figures on *Plate* XXXVIII (herein before referred to) illustrate our improved dredger hull with the bucket ladder, or it may be the suction pipe arranged at one side of the hull instead of in a central well as herein-before described, with reference to *Figs* 1 and 2, *Plate* XXXVII

The other part of our said Invention, viz, that having reference to the utilization of the exhaust steam from the engines of the ejector pump (when such are used) is illustrated on *Plate* XXXIX

The engines for working the bucket ladder are represented in horizontal section, the high pressure cylinder being marked A, and the low pressure cylinder B Steam from the boiler is led through the pipe C, and from the pipe C a branch D feeds the steam into the engine E of the ejecting pump F After passing through the engine E, the steam exhausts through the pipe G, and passes into the low pressure cylinder B of the main engines as indicated by the arrows, or otherwise the cock *g* on the pipe G is turned off, and the cock *h* on the branch pipe H opened, so as to

feed the exhaust steam (as indicated by the dotted arrows) into the valve chest of the high-pressure cylinder A of the main engines, which may be thus driven entirely by the exhausts steam from the engines E of the ejecting pump F. If, however, it should be desired not to use the exhaust steam from the engine E, it is only necessary to cut off communication with the main engines by means of the cocks or valves *g* and *h* and allow the steam to escape from the ejecting pump engines at the ship's side through the pipe I, the cock or valve *i* being opened to allow the steam to make its exit into the atmosphere.

J. W. B.

No CCI.

CIRCULAR ROOF IN IRON

[Vide *Plates* XL to XLIII]

Description of a Circular Roof in Iron, with working Calculations and Specification

THE occurrence of a circular room, $28\frac{1}{2}$ feet in diameter, part of a building of some importance, now under construction in Southern India, gave an opportunity to apply the principle of the dome, to the iron framing of its conoidal roof By this, cross ties are dispensed with, and the interior of the roof can be rendered so sightly, because appropriate, that a flat ceiling is not required A roof in the form of a conical dome may be defined in this case, to be a shell of combined framing and terrace masonry of the figure of a solid of revolution with a vertical axis and circular in plan Its tendency to spread at its base is to be resisted by the tenacity of a metal hoop or linked series of bars encircling the base of the dome To enable the roof to be practically designed, it is necessary to know the horizontal pressure per unit of length of arc at the base, the weight distributed over the rib rafters, further the minor strains, if difficulty in procuring suitable rolled joists compels a secondary trussing of the ribs

The calculations reduced to the simplest elements are as follows —

Let the roof framework and covering be considered a uniform conical dome, weighing 100 lbs, or 0 0446 ton per superficial foot, and suppose it as in the diagram, cut by a plane, at right angles to the circle of the base A reference may be here made to Professor Rankine's Applied Mechanics, Fifth Edition, page 267 The data are—

Angle of inclination $i = 22°$

Radius of the ring base $= 15·25$ feet

Height $Oi_1 = 6$ feet

Slant height of the cone $BO = \sqrt{6^2 + (15·25)^2} = 16·3$ feet

Weight of the roofing per superficial foot as above $= 0·0446$ ton

If P_x be the whole vertical weight of the roof BOB, it is

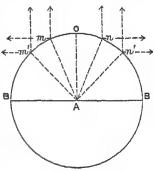
$=$ surface of cone BOB in feet $\times$ 0·0446 ton

$=$ circumference of base BB $\times \frac{1}{2}$ slant height BO $\times$ 0·0446

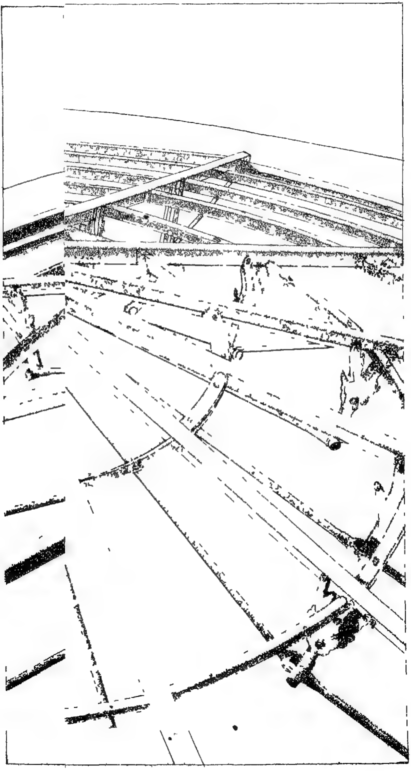
$= 2\pi\ (15·25) \times \frac{16·3}{2} \times 0·0446 = 34·8$ tons

The horizontal component of this downward pressure is P_x cotan $i =$ 34·8 cotan 22° $=$ 34·8 $\times$ 2·475 $=$ 86·1, say 86 tons. The intensity of this single radiating thrust, reduced to per running foot of periphery of the cone's base, is 86 $\div$ 2π (15·25) $= \frac{8}{10}$ ton per foot, all along the base ring outwards.

The relation between the tension of a ring, and the equable pressure radiating outwards upon that ring, is thus determined. Let BOBB be a ring cut in half by the transverse plane BB, and let the tension at each extremity of the semi-circle BOB be T. The radiating pressures Am, Am', &c., can be resolved into a succession of forces, one set perpendicular to BB, and another set parallel to that axis. So also can the forces An, An', &c., but the resolved forces, which are in this case parallel to BB are obviously equal, opposite, and coun-

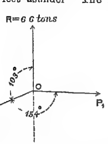


teracting, to the similarly obtained components of Am, Am', &c., consequently, only the forces perpendicular to BB, of all those resolved, are effective to produce tension at the points BB. That is the single force in the direction AO, if supposed carried along the whole diameter of the circle with simultaneous impulse, will produce the same tension T, at B and B, as the more numerous radial forces will, acting along the entire semi-circumference. Or, in other words, the tension T at any point B in the ring, will be the force in the radial direction AO per unit of periphery, multiplied by the radius of the quadrant, to the same unit. Broadly, the tension of the ring is the product of the radiating force per unit of periphery, and the radius of the circle.



In the present case, therefore, if the ribs of the roof are close together, the tension to be expected, and which must be met by the cohesion of the circumferential ring, is 0 9 ton × 15 25 feet = 13 7 tons

There are, however, 13 ribs in the actual roof, and the feet of each are 7 4 feet asunder The radiating pressure is also mostly collected at the feet of the ribs, and therefore amounts to 0 9 × 7 4 = 6 6 tons for each The feet of the ribs are to be tied by straight connections OP, OP_1 in the direction of the diagram



By Statics, R P sin 154° sin 103°
or 6 6 P 0 438 0 974

$$P = \frac{6\ 6 \times 974}{438} = 14\ 6 \text{ tons},$$

which is the tension on each of the 13 tie bars deduced by calculation

This is an extreme stress, not at all likely to be realized in practice, because there are two or three considerations which mitigate the theoretic radial forces The angle iron purlins bolted into five complete and concentric circles take off some of the tension, the material of the terrace is itself intercoherent, while a wall plate receives the dead weight of the border of the roofing, and again, something is gained from the friction of iron against stone bed plates

In originally preparing the following specification, upon which, with trifling exceptions, the ironwork of the roof was actually made, a tension of 12 tons in each of the 13 circumferential tie bars was contemplated, and seems sufficiently near the computed strain for a roof supporting no ceiling

Were a set of ribs in simple rolled sections procurable, no further calculation would be required for so moderate a span As it happened, and as generally is the case in India, a built rib of some sort had to be improvised The form of truss chosen to strengthen the necessary length of T-iron, is shown to scale in *Fig* 2 and is that of the inverted queen-post truss It may be useful to give the graphic delineation of stress as an example of that method, though a rougher approximation would suffice in practice The weight of the triangle HDK, shown on the "Plan of Loading," may be taken as $\frac{P_x \text{ ante}}{13} = \frac{34\ 8}{13} = 2\ 7$ tons G at a third of the length of the rib, is the centre of gravity of the triangle, and the struts BE and CF are placed in the "Section of Frame," with close reference to this point The supporting forces are by the principle

of the lever, at $A = \frac{9.8}{15} \times 2.7 = 1.8$ tons, and at $D = \frac{7.3}{15} \times 2.7 = 0.9$ tons. The downward forces due to the weight of the roof, and its covering, may be considered proportional to the shaded segmental areas of *Fig* 1, and are for the points A, B, C, D, of *Fig* 2 along the rib 0.8, 1.0, 0.75 and 0.15 ton, respectively. [*Plate* XLIII.]

The corresponding "Diagram of Stress," *Fig* 3, shows the strains along the lines AB, AE, BE, to be by scale, respectively, 3.75, 3.5, 0.9, tons. The lines of the Stress Diagram are colored similarly to the bars in the "Section of Frame," *Fig* 2, to facilitate reference. [*Plate* XLIII.]

It has thus been ascertained from the foregoing calculations, that the tension of the ring is from 12 to 11½ tons, the compressive strain on the rib 3¾ tons, the tension on the tie bars 3½ tons, and the stress on the braces, about a ton. Making due allowance for shearing strain on bolts, areas of bolt holes, and taking the safe load on wrought-iron in tension at 5 tons per square inch, the specification stands as follows, while the details are drawn to scale on the plan of the roof.

Iron Roof Specification

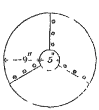
Round Room

The roof to have an iron framing composed of 18 trussed ribs, set in shoes, distributed at equal distances on the top of the wall, connected at top by a collar, and at the shoes by T-iron tie bars. The inner diameter of the room is 28½ feet, and the shoes come up to this circumference.

Seen from above, the roof to have the surface of a cone, whose diameter at base is 30½ feet, and height 6 feet.

18 *T-iron rafters.*—The conical surface is to be divided into 18 equal parts, by as many ribs or rafters.

Each rafter to be of T-iron 2½ inch top table, 3 inches deep, ⅜-inch thick, and 16 feet long.



1 *Plate Iron Collar.*—An iron annular collar for the apex, to be provided. The inclination of side to be 22°, and to be made of ⅜-inch best iron plate. The opening in the centre is to be 5 inches in diameter. The diameter at edge to be sufficient to give a slant length of 9 inches. The collar may be made up in three or more pieces, rivetted together with ½-inch rivets.

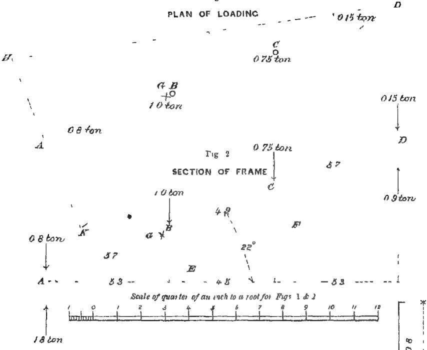
CIRCULAR ROOF IN IRON

Fig 1

PLAN OF LOADING

Fig 2

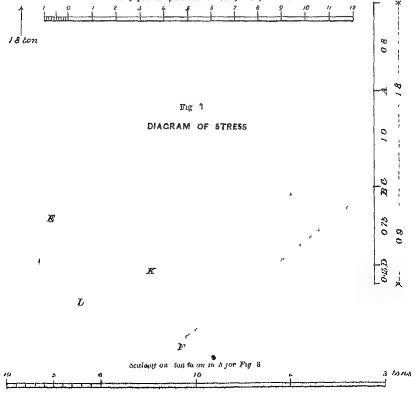
SECTION OF FRAME



Scale of quarter of an inch to a foot for Figs 1 & 2

Fig 3

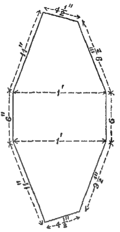
DIAGRAM OF STRESS



Scale of one ton to an inch for Fig 3

78 *Bolts and nuts ½-inch for the collar and rafters*.—To this collar the several rafters will be bolted, by ½-inch screw bolts and nuts, three a side of the T-iron rafter, spaced to three inch pitch.

Fig 1

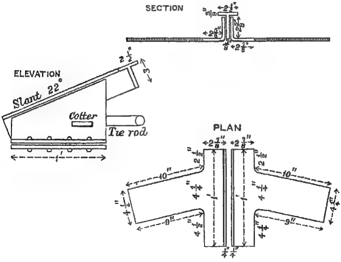


13 *Shoes complete*.—The lower end of each rafter will be rivetted to a shoe formed as follows of ¼-inch plate —

Fig 1 is this wall plate, on which a pair of ledge plates, shown in *Fig* 2, will be rivetted by four ⅝-inch rivets, so as to clamp the feather of the T-iron rafter.

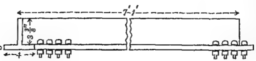
The feather of the T-iron to be secured by four ⅝-inch rivets, between the ledge plates, and the ledge plates themselves to be rivetted by similar rivets to the wall plate, *Fig* 1. A cotter for the tie-rod, equal to 3½ tons pull, to be formed at the proper place in the ledge plates.

Fig 2

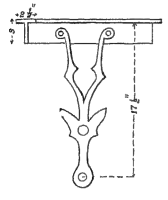


13 T-*iron tie-bars with* 208 *three-quarter-inch bolts and nuts*.—Each wall plate or shoe will be tied to those adjoining, by T-irons 7 feet 1 inch

long, section 4 inches by 4 inches, and $\frac{3}{8}$-inch thick, laid flat, and fastened to the wall plate by four $\frac{3}{4}$-inch bolts and nuts a side, or by eight bolts and nuts in all, at each end of the T-irons



26 *Brace bars complete*.—The rafters will be braced by two compression bars, placed 5 feet 7 inches from the lower end of the rafter, and at a point 4 feet 10 inches further on they will also have a tie-rod in three pieces, of one inch diameter, jointed and fitted as indicated in the plan The compression bars to be formed of two plates of forged iron cut and welded into the annexed pattern, nowhere less than $1\frac{1}{4}$ inch broad, and $\frac{3}{8}$-inch thick, laid side to side, rivetted with one rivet in the middle To have an eye for admission of the inch tie-rod bolt, and eyes for $\frac{1}{2}$-inch bolts above, which are to fasten the braces to the T-iron rafters

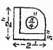


13 *Tie-rods in 3 pieces each*.—Tie-rods of one inch diameter to be provided in three lengths for each trussed rib They will bolt on one inch bolts and nuts, be duly enlarged at ends while the slant tie-rods will at the ends entering the shoes, be formed to a jib and cotter attachment, by which they can be tightened up. The plan shows the manner in which this is arranged

13 *Purlins* 130 *Bolts and Nuts $\frac{3}{4}$-inch diameter*

Purlins.—The purlins will be of 2-inch angle iron, $\frac{3}{8}$-inch thick, placed at points, $1' 1''$, $2' \frac{3}{4}''$, $2' 5''$ and so on, beginning from the end of each rafter on the wall The lengths will therefore be, $6' 10''$, $5' 10''$, $4' 8''$, $3' 6''$, $2' 4''$, of the 5 purlins per bay contemplated The ends of each purlin will be finished off by a forged flange to abut on the feather of the rib rafter, and will be bolted to it by one $\frac{3}{4}$-inch bolt. The purlins to be curved to the radius

No	Length
13	6′ 10″
13	5′ 10″
13	4′ 8″
13	3′ 6″
13	2′ 4″

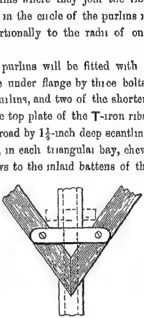


of the cone at the various points There will thus be required 5 purlins consisting of 13 pieces each

Note.—The tie-bars have been made strong enough to confine the forces transmitted by the trussed ribs in equilibrium, but it is open to the manufacturers to obtain greater immunity from breaking strain, by bolting lengths of 2-inch angle iron below the purlins where they join the ribs and butt against each other The tension in the circle of the purlins is that of the tie-bar system, reduced proportionally to the radii of one and other

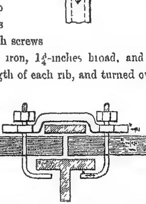
169 *quarter-inch bolts and nuts*.—The purlins will be fitted with a wooden batten, which will be bolted to the under flange by three bolts, $\frac{1}{4}$-inch diameter, in the case of the longer purlins, and two of the shorter The top of these battens to be flush with the top plate of the T-iron ribs

Teak reepers.—Teak reepers of $2\frac{1}{4}$-inch broad by $1\frac{1}{4}$-inch deep scantling to be laid at an angle of 27° with the ribs, in each triangular bay, chevroned, and screwed with $2\frac{1}{4}$-inch wood screws to the inlaid battens of the purlins. The reepers will be spaced 5 inches apart from centre to centre, to suit square tiles of about $4\frac{1}{2}$-inch sides The reepers to be notched $\frac{1}{8}$-inch on to the purlins



Hoop iron bands.—The reepers presenting a flat joint to each other on the top plate of the T-iron rib, are still insufficiently secured A piece of $1\frac{1}{2}$-inch stout hoop iron, 7 inches long, to be screwed across the junction of every reeper, by two $\frac{3}{4}$-inch screws

13 *Bars over T-iron ribs*.—A bar of iron, $1\frac{3}{4}$-inches broad, and $\frac{1}{4}$-inch thick, to be laid along the whole length of each rib, and turned over to grip the collar



52 *Cleats*.—Each bar to be held down by cleats of one inch by $\frac{1}{2}$-inch bar iron.

104 *Quarter-inch fang bolts*.—The cleats to be secured to the T-iron top plate, by $\frac{1}{4}$-inch fang bolts

Wall plate for reepers.—A wall plate of teak to be laid clear of the iron tie bars, along the extreme circumference of the base of the cone,

as shown in the plan, and the ends of the reeper to be screwed to it by $1\frac{3}{4}$-inch wood screws

Note.—Battens of a stronger section may be placed in similar chevroned fashion, one foot apart from centre to centre, to suit Bengal flat tiles The purlins being circular on plan, while the reepers scarcely bend, are thrown slightly downwards, but this is little noticed from below, and gives the impression of a curved and not polygonal surface

Studding.—To prevent any possibility of the tiles sliding on the chevroned battens, $1\frac{1}{4}$-inch sharp nails are to be driven bristling at points on the battens $3\frac{1}{2}$ feet apart

Sloping terrace covering.—The roofing above the teak wood reepers to be of the description known in Madras Specifications, as "Sloping Terrace" The covering to consist of three courses of tiles 5 inches square, of which the first to be laid on the reepers with mortar between the joints, the second and third courses are set in mortar Over these three inches of fine concrete well beaten to a uniform surface Upon this imitation, Italian tiles are formed, by raising ridges of fine concrete The whole to receive a coat of lime plaster, having 20 lbs of goat hair allowed, and 10 lbs of coarse molasses, per 100 cubic feet of plaster material

Coloring.—The imitation tiling is to be colored as may be ordered, by rubbing in pigment when rendering the plaster

The ironwork was made by Messrs Nicol and Co, in Bombay, costing, delivered there Rs 1,500. Setting up in position exclusive of carriage, cost about Rs 250 more, which includes the items connected with the fitting of the reepers not necessarily supplied with the framework The rates for woodwork and terracing being purely local, are not of present interest, and illustrate no general principle

No CCII

MOULDING AND DRYING SHEDS FOR ROOFING TILES

[*Vide* Plate XLIV]

BY H. BULL, ESQ, *Assist Engineer, Military Works, Agra*

THE annexed drawings show a form of shed which is not only more convenient for working in, but much more economical than the ordinary form

The shed is divided into three parts The two ends which are similar, are for the drying, the middle chamber for the actual operation of moulding Each end is divided into four longitudinal compartments, with a range of shelves on either side The shelves are formed by a series of corbellings or cornices, the offsets (or insets if there were such a term) being shown in the drawing. The corbelling bricks should be partially burnt, the rest may be kucha The extent of corbelling in present instance is suitable for 10″ bricks. If larger bricks be available, the necessary width of shelves may be secured in fewer layers Thus with 12″ bricks, the projections might be made $5\frac{1}{4}'' \times 5\frac{1}{4}'' \times 5''$, making $15\frac{1}{2}''$ as shown, this would give room for an extra shelf in each range

It should however be noted, that the height of 5 inches below the corbelling should not be lessened, in order to allow room for half round tiles, as also for a free circulation of air.

The width of shelf is suitable for a tile moulded 16″, or a little over, the flat tile will in any case overhang a little on account of the buttons, and if the rest do the same, no harm is likely to accrue

The roof of the centre chamber is raised above that of the two ends,

so as to allow light to enter, they are connected roughly by bamboo jaffries The trusses are formed of common bullies 3 or 4 inches thick There is room in a shed of this description for moulding and drying 2,000 flat, and 2,000 half round or semi-hexagonal tiles, or allowing five days before removal for the manufacture of 800 tiles a day, or quarter lakh per month, or say two lakhs in a season of eight months

With the masonry of partly burnt and partly kucha bricks set in mud, and a 3" thatched roof, the cost would be about Rs 500, or about Rs 2-8 per 1000 on a season's manufacture

H B

MOULDING AND DRYING SHEDS FOR ROOFING TILES

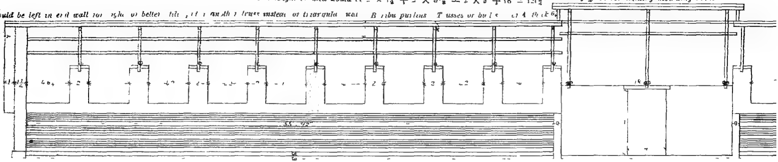
LONGITUDINAL SECTION

showing one end & in the middle part for Tables

The total length of shed would be [illegible] $= 126\frac{3}{4}$

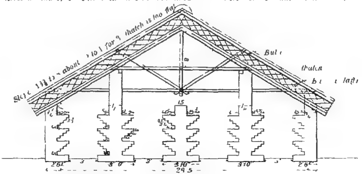
should be left in end wall for light or better [illegible] *truss instead of triangular* [illegible] *Bambu purlins* [illegible]

Bambu jaffrea for lighting moulding room



CROSS SECTION

[illegible] *shelves could be brought out the necessary width in 3 layers instead of 4* [illegible]
might be [illegible] *shelves instead of 4* [illegible]



On each line of shelves there is room for $4 \times$ [illegible] $= 200$ [illegible] 400 [illegible]
Each end therefore will contain $8 \times 200 = 1600$ 3200
Both ends $2 \times 1600 =$ [illegible] 6400
There is thus ample room in each shed for 8 moulders making [illegible] *each*

No CCIII

IRON BRIDGE OVER MISSOURI RIVER AT ST JOSEPH.

[*Vide* Frontispiece and Plates XLV, XLVI and XLVII]

Communicated by LIEUT.-COL J G MEDLEY, R E

Dated, Rawul Pindee, May 1876

THE following report is compiled from some papers and drawings which I brought away from the United States nearly four years ago, and a *resumé* of which I think will be interesting to many of the readers of the Roorkee Professional Papers

They comprise—first, the Specification of a large Iron Railway and Road Bridge lately constructed over the Missouri River, at the town of St Joseph, and which is of a pattern altogether different from any of those ordinarily adopted in Europe or India The advantages claimed for it by American Engineers being greater economy, and an absence of the objections commonly made to rivetted structures, especially in countries liable to extreme ranges of temperature

To the Specification of the bridge in question, is added the First Report of the Engineer-in-Chief, Colonel Mason, by whom the bridge has since been completed and opened for traffic, through whose kindness I obtained these papers, and with whom I visited the works while in progress

The accompanying Photograph and *Plate* No XLV, are not drawings of the bridge in question but as they represent one *precisely similar* in description (and I think also in length of spans) they will serve to illustrate these papers

The third paper deals with the Physical Characteristics of the Missouri River, with special reference to the training works employed to guide the stream through the St Joseph Bridge, which have been quite successful, and which will be of interest, as this river is in all essential

points very similar to the Chenab Its navigation is attended with the same difficulties, which however, in this case as well as in that of the Upper Mississippi, have not prevented the employment of steamers of a suitable pattern, of which I sent a description some time ago, (*see* No CL, Professional Papers on Indian Engineering, Second Series)

At a time when so much of our best Engineering talent is employed in bridging the great rivers of the Punjab, and in guiding their streams with more or less success, I think it will be interesting to see the peculiarities of American practice in the same direction

J G M

SPECIFICATIONS FOR AN IRON BRIDGE OVER THE MISSOURI RIVER AT ST JOSEPH, DESIGNED FOR BOTH RAILWAY AND ORDINARY TRAFFIC

Location of Bridge—The Eastern terminus of the bridge shall be within the present corporate limits of the city of St Joseph, and the Western terminus shall be in the county of Doniphan, in the State of Kansas, opposite said city of St Joseph Said bridge will be located within the limits aforesaid by the Chief Engineer of the St Joseph Bridge Building Company, at such point as, in his opinion, will secure the construction of said bridge at the least cost, due regard being had to the cost of right of way, of bridge approaches, of the bridge itself, and the river protection

Description of Bridge—*Number of Piers—Length of Spans*—The bridge will consist of one pivot draw span four hundred (400) feet in length, and three fixed spans of three hundred (300) feet each in length, in the order in which they are named, beginning at the East abutment, each span being measured from the centre of piers

Description of Piers—The bridge will rest upon structures of masonry numbered and described as follows, and generally built in accordance with the plans attached to, and forming a part of these specifications

No 1 An abutment on the East bank with curved wings

No 2. A pivot draw pier of the plan shown in the drawing, and of sufficient size under the coping to receive a circle of thirty-four (34) feet diameter.

No. 3. A pier ten (10) feet wide and twenty five (25) feet long under

the coping, the bridge seats being arranged to receive the bearings of the draw span on one side, and take the bearings of a two hundred and eighty-five (285) feet span on the other

Nos 4 and 5 Piers nine (9) feet wide and twenty-five (25) feet long under the coping

No 6 An abutment on the West bank with curved wings

Height, Length and Width of Piers.—The height of the abutments and piers shall be such that the lower side of the chords of the superstructure shall be ten feet high in the clear above the high water of 1844, as determined by the Engineer The abutments and piers shall be constructed according to the plans and sections annexed to, and forming a part of this contract, and after detailed drawings to be hereafter furnished by the Engineer

Foundations of Abutments and Piers.—*No* 1.—The foundations for the East abutment shall be excavated in the clay to a depth of five feet below extreme low water, and the excavation shall be filled to a depth of three feet with concrete, made and put in place in the manner hereinafter described

No 2.—Pivot Draw Pier—shall be founded upon the rock bed of the river on an inverted caisson, which shall be built and sunken substantially in the same manner as were the river piers for the Illinois and St Louis Bridge, across the Mississippi at St Louis

Nos 3, 4 and 5—Piers—shall be founded and sunken as described for pier No 2

No 6.—West abutment The bridge seat shall be sunken to the rock as described for the piers, and the wings *may* be upon concrete foundations, such as are specified for the East abutment

Masonry.—*Stone*.—The work will consist of sound, durable lime, magnesian lime, or sandstone, from such quarries as may be accepted by the Chief Engineer, and shall be free from shakes, dry cracks, or other imperfections

Ashlar—Backing—Concrete—Courses to be levelled up—Sizes of Courses.—The exterior of the abutments and piers shall be rock-faced ashlar, pitched to the *batter* shown by the drawings, cut on the beds and joints and backed with sound stone, fitted close to place and laid in full beds of mortar The backing or filling of the piers may, however, consist of concrete, made according to the specifications for the same, each course

to be fully completed and levelled before the commencement of another At least one-third of the stone shall be over eighteen (18) inches in height, one-third from fourteen (14) to sixteen (16) inches, and not to exceed one-third twelve (12) inches

Stones to be on natural bed—Beds and Joints—Vertical Joints—Headers—Starlings—Dowelling—Bond —All stones shall be cut to lie on their natural beds, which are to be dressed square and true throughout to a three-eighths ($\frac{3}{8}$) inch joint The width of all beds shall be at least one-half greater than the height of the course, and vertical joints shall be dressed square for a distance of nine inches from the face There shall be headers in each course—one for every two stretchers—two and a half feet long, in the face of the piers, starlings to be formed of three stones, as shown on plan. The courses of stone laid in the upper and lower starlings and shoulders shall be dowelled together as follows — Through each stone, after being laid, a hole shall be drilled and continued five inches into the stone beneath, a dowel of round iron, ten inches in length, and one inch diameter, shall be inserted, and the interstice filled with grout No dowel to be placed within six inches of any joint All courses shall break joints with each other not less than one foot

Starlings to be Bush-hammered—Draft line two inches —In addition to the cutting of beds and joints, the whole upper face of starlings between high and low water shall be bush-hammered, also, copings of piers and the grooves in the pivot pier for floats On all piers there shall be a margin draft two inches wide, chiselled on angles, and string courses, and the courses and copings of wingwalls of abutments shall be cut according to detailed plan

Coping of Pivot Pier —Coping shall be sixteen inches thick, the coping of bridge rests shall be long enough to cover the whole width of piers, and the coping of pivot pier shall extend unbroken at least four feet from the face, and shall be fitted to place, so that adjacent stones shall break joints at least one foot

Mooring Rings —Two rings, made of one and a quarter inch round iron and six inches clear diameter, shall be firmly secured in the down-stream end of each pier

Angle Irons —On the point of the upper starling of each pier, there shall be bolted an angle iron in a single piece, long enough to extend from below low water to the string course, four inches wide on each face, and

one-half inch thick, and firmly secured to the pier by a wedge or bolt at each joint in the masonry

Mortar—how proportioned—Cement to be approved of by Engineer—The mortar shall consist of one-half hydraulic cement, of such brand as may be accepted by the Chief Engineer, and one-half clean, sharp, river sand

Pointing—The whole work exposed to view shall have the joints picked out and pointed with a tool

Concrete—*How proportioned*—The concrete shall consist of two cubic yards of limestone, broken so as to pass through a two and a half inch ring, and screened, three and a half barrels of cement, as aforesaid, and three and a half barrels coarse river sand, the whole to be mixed by spreading the sand on a layer of the stone, and the cement on the sand, pouring on water with a common watering pot, and thoroughly turning the whole over till each stone is covered with mortar All concrete made must be used immediately That put in for foundations of abutments must be laid in about eighteen inch courses, and each course thoroughly rammed while fresh

To be fresh ground—Cement condemned to be destroyed—All cement used shall be fresh ground and subject to frequent inspection, and any that may, from any test applied, be found to be of inferior quality and condemned, shall be destroyed immediately

Draw Rests—*Cribs for—Size and description of Timber—Manner of sinking Cribs—Pockets to be filled with Rip-rap—Cribs—how to be finished—To be lined to the batters—Drift bolts—to be dressed—Sheeting of—Protection to Draw Span*—Cribs for upper and lower draw rests shall be framed according to plans of 12″ × 12″ pine or elm sticks, in courses six inches apart, with cross ties of oak or elm 10″ × 10″, dove-tailed $1\frac{1}{2}$ inches into the side courses, and locked into the centre course, the whole to be secured by three-fourths inch square drift bolts, twenty two inches long, two at every intersection These cribs shall be sunken to the bed rock on an inverted caisson, in the same manner as described for the piers—the pockets—or bins formed by the timber to be filled with rip-rap, these cribs to be carried to within one foot of low water, and be finished to a proper height to receive the draw span, when open, and they shall be lined to the several batters shown on plan, the outside to be constructed of 4″ × 10″ oak plank, halved at the corners to form a continuous course, and securely spiked with twelve inch drift bolts of one-half inch square iron,

the inside courses to be of two inch pine or elm plank, those running lengthwise to be doubled, so as to level up to the outer courses, the cross ties to be of single two inch plank, the whole to be spiked at every crossing with six inch wrought boat spike, the whole structure above the timber cribs to be adzed off smoothly to the several batters required The nose of the ice breaker to be sheeted with half inch boiler plate, two feet wide, bolted to steel rail of T form, and secured to the draw rest in the same manner as that at the Hannibal Bridge

Rollers—General plan and character—Width between trusses —Between the draw rest and the first pier, there shall be fitted floats of white pine timber, the sides composed of double chords of a *Howe truss*, four courses high, of 12″ × 12″ chords These trusses shall be twenty-six feet wide from out to out The floats shall be fitted with cast-iron rollers at each end, running in the grooves made in the masonry of the pivot pier, and in the draw rests, with sufficient play, so that they can rise and fall freely with the water

Superstructure —*Description* —The superstructure shall be of iron, similar in general plan and equal in character of workmanship and materials to the bridge over the Mississippi river at Hannibal

Spans—how constructed —The height of the girders shall be, for the two hundred and eighty-five (285) feet spans twenty-seven (27) feet, for the draw span twenty seven (27) feet at the ends, and forty (40) feet at the centre The clear width shall be eighteen (18) feet between posts

Contractors to furnish Working Drawings —Before construction is commenced, working drawings shall be submitted to the Chief Engineer of the Bridge Company for his approval

Cast-iron —All the spans shall be built entirely of cast and wrought-iron The cast-iron parts of the fixed spans may be the upper chords, caps and pedestals of posts, bed plates and washers of the draw spans, the caps and pedestals of posts and washers in bridge, the centre spider plates, and stiffening pieces, wheels and segments of turntable, and track under same, and racks, pinions and brackets for turning

Wrought-iron—Iron to be tested—Iron to be rejected—All iron to be finally tested —All other parts of all the spans shall be of wrought-iron The wrought-iron shall be of the best quality, free from any imperfections effecting its strength It shall, before being used, be subject to thorough tests in a hydraulic press, and all lots from which any selected bars shall

break under a strain of fifty thousand (50,000) pounds to the square inch shall be rejected. All the bars used in the bridge shall be subsequently tested to a strain of twenty thousand (20,000) pounds to the square inch of section, and shall, while under tension, be struck with a hammer, and if any show permanent set, or show signs of imperfect welding, they are to be rejected

Maximum tensile strain allowed on wrought-iron—Maximum compressive strain—Maximum strain on Floor Beams—The different parts of the structure shall be so proportioned that a rolling load of two thousand five hundred (2,500) pounds to the running foot, in addition to the weight of the structure itself, and the track thereon, the latter estimated at six hundred (600) pounds per lineal foot, shall bring on no part a greater strain per square inch of sectional area than is shown in the following table, to wit —For parts which receive their full load when the entire length of the span is loaded, 12,000 pounds For parts which receive their full load when three-fourths ($\frac{3}{4}$) of the entire length of the span is loaded, 11,000 pounds For parts which receive their full load when one-half ($\frac{1}{2}$) of the entire length of the span is loaded, 10,000 pounds For parts which receive their full load when one-fourth ($\frac{1}{4}$) of the entire length of the span is loaded, 9,000 pounds For single panel systems, 8,000 pounds The factor of safety for compressive strains shall vary similarly from four (4) to six (6) as calculated by "Gordon's formula," and a weight of two thousand five hundred (2,500) pounds per running foot shall in no case strain the floor beams over eight thousand (8,000) pounds per square inch, calculated upon the sectional area of the lower flange

Workmanship to be of the best quality—Upper Chords to be Callipered—All the workmanship to be of the best quality The upper chords, if of cast-iron, shall be callipered, and if found to be one-eighth inch less than the required thickness of metal, shall be rejected

Greatest error allowed in length of Bars or in diameter of Holes—Connecting pins to be turned—The deviation from a right line shall not exceed one-quarter inch in a twelve (12) feet column All abutting joints shall be planed or turned, all pin holes in wrought-iron shall be drilled No bar of iron having an error in length between the pin holes of over one thirty-second of an inch, or in the diameter of the pin holes of over one-hundredth of an inch shall be allowed The connecting pins shall be turned, and no error of over one-hundredth of an inch shall be allowed

Iron to be cleaned and painted—Machine work to be protected —All the ironwork shall, as soon as possible after being cleaned, be painted with one coat of oxyd of iron paint and oil All machine work, before leaving the shop, shall be covered with a coat of white lead and tallow

Camber —The fixed spans shall be built to a camber of three (3) inches. All spans shall return to the original camber without readjustment after having been tested

Turntable—Platform for —The draw span shall be provided with a turntable of similar plan and equal in all respects to the turntable under the draw at Hannibal It shall be furnished with turning gear, with friction wheels, to be turned by levers, and so constructed, that two men shall be able to turn the draw at right angles to the line in one and a half ($1\frac{1}{2}$) minutes when there is no wind blowing The contractor shall also furnish a steam engine, shafting and other attachments to move and handle the draw, of similar construction and proportional power to those in use at Quincy and Hannibal, also the platform on which to place the same

Track and Flooring of Bridge —*Floor-beams—Screw-bolts—Iron Rails—Carriage tracks* —Upon the floor beams shall be laid, for a railroad track, two pairs of white pine stringers, free from black or rotten knots, shakes or any imperfections that effect durability or strength, and large enough to size $7'' \times 16''$ after being planed, placed one-half inch apart, with blocks or keys between, and long enough to reach across two (2) panels, breaking joints, and secured by four and three-fourths ($4\frac{3}{4}$) inch round screw bolts at each joint, or over each floor-beam In the centre of each panel there shall be a strut $3'' \times 12''$ with a three-fourth ($\frac{3}{4}$) inch round bolt, having screw and nut on each end, and passing through both pairs of stringers The iron rails shall be of such form as may be hereafter chosen by the Engineer The stringers, outside the track-stringers, shall be four (4) in number, $6'' \times 14''$, and the ties shall be of oak $6'' \times 8''$, eighteen (18) feet in length, and placed twenty-two (22) inches apart between centres The whole floor shall be planked with two (2) layers of two (2) inch white or burr oak plank, laid as the Engineer may direct The roadway shall be protected by a strong railing on each side.

Side-walks —A side-walk, four (4) feet wide in the clear, shall be built outside the trusses on each side of the bridge, said side-walks to be supported by iron brackets, properly bolted to the bridge, to be floored

with two (2) inch pine plank, and provided with a railing upon the outer side

Painting.—*Portion of bridge to be painted with Mineral Paint—Portion of bridge to be painted with pure White Lead*.—All the wood, track stringers, iron floor beams, lower lateral rods, suspension bolts, washers, &c., shall be painted with two coats of dark-brown mineral paint, from the Brandon, Vermont, works, mixed in linseed oil. All the rest of the ironwork of the bridge shall be painted with two coats of the best brand "pure white lead" and linseed oil, shaded to a drab color.

Alterations or additions required by Chief Engineer, to be performed without extra charge.—If at any time during the construction of the bridge, it shall be found necessary to add to the structure described in the above specifications, or to alter the same in order to make a complete and permanent bridge, the additional work shall be performed and the material furnished by the contractors without extra charge—it being the object of this contract to provide for the complete construction of a bridge ready for use, the contractors furnishing all materials, labor, tools, plant false and temporary work of every description.

Sub-contracts to be approved of, and sub-contractors to be responsible to Chief Engineer.—No portion of the work shall be sub-let without the consent of the Engineer of the Bridge Company, and it shall be a condition of any sub-contract made, that the sub-contractor may, at any time, be dismissed from the bridge if the work performed by him is not satisfactory in progress and quality to the Engineer of the Company.

First Annual Report of the Chief Engineer

February 13th, 1872.

Before reporting the present condition of the work, it may be interesting to recall a few of the dates at which some of the more prominent portions of the work were begun, and which may serve as guides to indicate the progress made.

On the 1st of February of last year, an engineering corps was organized, and a preliminary survey begun. On the 15th of March following, the first report was made, and approximate estimates for a Bridge and Shore Protections were submitted.

Directions to prepare plans and specifications for the bridge were received about the 20th of March. An invitation for bids upon the work

according to the plans presented, was first published the 4th of May, and the time for receiving them extended to the 10th of June

On that day the contract was awarded to the Detroit Bridge and Iron Works, and steps were immediately taken to begin the work

In order to sink the caissons for the piers to the rock by the system adopted (the pneumatic) a large amount of heavy and costly machinery was necessary, and considerable time passed before it could be got together and set up ready for use, and this time was employed by the contractor in accumulating material and perfecting his arrangements

The machinery was first started at work, sinking the west abutment, known as Pier VI, on the 9th of November, and the caisson was safely landed on the rock the 7th of December. Pier V, the next piece of masonry east, touched rock the 31st of January last The exceeding coldness of the season greatly hindered the work on both piers

Work was begun on the Breakwaters and Shore Protections between the bridge location and the point of land north-east of Elwood, on the 27th of September They will be finished the 17th instant

The condition of the work at this date is as follows —

The West Abutment is finished Its foundation is hard limestone rock, sixty-one feet three inches below high water

Pier V is landed on the same stratum of rock that supports the West Abutment, and its foundations is sixty-four feet two inches below high water. All work except pointing the joints is finished below medium high water, and seven days work with a gang of masons will complete the pier *

In sinking Pier V. and the West Abutment, strata of sand, coarse and fine, were passed through for thirty feet, then stiff blue clay five feet, and lastly, a deposit of coarse gravel and boulders, through which flows a stream of water of mean temperature, and entirely separate from that in the river.

The caisson for Pier IV is finished and lowered from the ways upon which it was built to the sand bed of the river, five feet below the surface of the water The machinery for sinking it is set up and connected with the engines, the steam derricks with which to lay the masonry at the proper time, are ready, and to-morrow the sand pumps will begin work. †

* March 5th, 1872 This pier is now finished

† March 5th, 1872 The pumps were set at work on Pier IV the day this paragraph was written, and the suction pipe reached rock to day The rock will be cleaned off and concreting begun by the 10th instant The stratum of clay was thinner, but that of boulders thicker than at Pier V, and the surface of the rock is sixty five feet six inches below high water The masonry is built to within six feet of high water

Enough timber is on hand to build the caissons for Piers II. and III and the draw-rests The iron trusses with which to suspend the caissons for Pier II and the draw-rests while building, are well under way at the contractor's shops, and the setting up of the caisson for the upper draw rest and ice-breaker will begin as soon as the ice breaks up in the river A large quantity of plank for the draw-rests is delivered, and three-fifths of the rip-rap for them is piled on the bank at the east end of the bridge The caisson for the upper draw-rest is forty feet wide by sixty feet long, and its foundation will be about sixty-eight feet below high water

Of the dimension and backing stones to be used in the work, seven-eighths are delivered, and seven-tenths of the quantity necessary to complete, are cut, marked, piled in courses in the yard at the west end of the bridge, and ready to be laid The stones already cut embrace nearly all the bush-hammered and moulded work

The material used for the masonry is a beautiful "magnesian" limestone, weighing one hundred and forty-four pounds per cubic foot when dry It is brought from "White's Quarries," on spring Creek, Kansas, near the line of the St Joseph and Denver Railroad, one hundred and eight miles west of the Missouri River The thickness of the courses varies from twenty inches to three feet, two feet three inches being about the average

The severest test of the ability of this stone to endure frost without injury has been afforded this winter Nearly all the larger blocks, those from which the bridge-seats and string-courses are cut, were quarried during the excessive cold weather of last November, and the quarrying of dimension stone was not stopped until in January, when a sufficient quantity for the work was ready for transportation , but not one stone of the stratum used has been split or checked by frost either at the quarry or in the yard The large quarries on the Mississippi river and in Northern Illinois are usually closed about the 1st of November, and even then sometimes a large percentage of the last stones taken out are shattered by freezing before they can "season" properly

The contractor is well supplied with first class workmen, machinery, engines, tools and boats Within the past month he has duplicated the power used for working the sand pumps, and put up an additional pump,

so that we are now able to sink a caisson in nearly one-half the time required for those already sunken

All the machinery, tools and false works applicable thereto, have been set up and built with a view to their use in raising the superstructure when the proper time arrives

The arrangements in the stone yard at the west end of the bridge are the best I have ever known for handling the same quantity of material with rapidity, economy, and without confusion Four thousand cubic yards of cut stone were at one time so stored and marked, that any particular course could be removed without disturbing another, and seventy cubic yards of dimension stone, averaging one and a quarter tons weight each, have been unloaded from the cars, and placed in the cutting yard by the ordinary working gang in an hour

No casualty has occurred more serious than the fall of a workman from the false works to the ground, a distance of twenty feet, by which he was unfitted for labor about ten days

A thorough examination of the work done and materials furnished, shows that seven-tenths of the substructure is an accomplished fact

Seven thousand two hundred and fifty cubic yards of rip-rap, all that will be needed, is piled near the west end of the bridge, ready to be used for facing and protecting the banks of the approaches It is purposed not to build these banks until after the subsidence of the spring floods

Seven pieces of work are built to act as breakwaters, controllers of the current in the river, and shore protections A part of these, designated 1, 2, 3 and 7, on the accompanying map, (*Plate* XLVII,) were only intended as temporary, and were built more to enable the foundations of those meant to be permanent to be properly laid The breakwater marked 3, is about eight hundred feet long, and was built of small cottonwood and willow brush sunken to the bottom by weighting with sand The brush were kept in position in the current, before resting on the bottom, by small piles driven by hand with a wooden maul The channel, much of the way across, was from eight to eleven feet deep, with a current swifter than in any other part of the river for two miles each way The brush were piled about a foot higher than low water, and covered with a layer of sand sufficient to keep them from floating away should the water rise When work was stopped, the surface of the water at its upper end was on the channel side, four-tenths of a foot higher than on the shore side, and a rise of two feet

in the latter part of November entirely submerged it and nearly filled the channel below it with sand. This structure, although intended to exercise only a temporary influence, entirely changed the low water channel of the river in ten days time, and it still remains complete.

The breakwater running southeasterly from the east end of the "Wathena macadamized road," marked 4 on the map, (*Plate* XLVII.,) is two thousand one hundred feet long, sixty feet wide at the base, thirty at medium high water, and contains fifty-six thousand cubic yards of brush, timber and sand, after being weighted with a wall of rip-rap averaging twelve feet wide and three feet high, (*vide* section on *Plate* XLVI.) At the point where this work was begun, the river hugged the Kansas shore, and was rapidly cutting away the land. The channel, at low water, was five hundred feet wide, and twenty feet deep, and the velocity of the current was four miles per hour. The brush and timber were kept in position until sunken to the bottom, by piles about ten feet apart, well driven with a steam pile-driver. More than seven hundred piles were used in building the foundations. When the work had progressed so as to materially contract the channel, the current scoured the bottom until a depth of twenty-six feet was reached. At this time the temporary work, 3, already described, was designed and built for the purpose of turning the current away from the larger work, or at least of materially reducing its volume. The success of the plan equalled our most sanguine expectations, and the main body of the river formed a channel a thousand feet to the east of its old bed. The bottom of this old bed was now but five feet above a stratum of stiff clay, and but fifteen feet above the rock, and the breakwater was built across it before time was given for it to fill with sand and mud deposits.

The second channel, when crossed, was wider and the current swifter, but with an average depth of only ten feet. A bar about two feet under water, near the east shore of this channel, was reached, and a mote built of the same kind of materials used in the breakwater.

The whole width of water way in the river opposite this work is, at its present height, less than five hundred feet, and the effect of the work has been to give the river a new channel half a mile east of that in which it flowed last October.

The sand bar along the east shore of the river is rapidly cutting away. The wall of rip-rap on the breakwater is about two feet above the higher parts of the bar opposite its easterly end, and it is expected that the first

flood will cut through the bar at the low ground below Blacksnake Creek, and find its channel in the Bayou and along the high bank of the east shore to a point some distance below the bridge The old channel between the breakwater and the Kansas shore, as far down as shore protections 5 and 6, will soon be filled with sand and silt deposits to a height above ordinary floods The breakwater is so constructed, that it may be undermined by an impinging current until it shall sink to the bed-rock, and still leave the rip-rap wall at nearly its present height The current in the river can never have a velocity sufficient to carry it away while the present space is left between its east end and the east shore, except in the event of a cut-off along the foot of the east bluffs immediately above the city, and I am confident that, even in that case, it would direct the current and save the point of land on the Kansas shore below Elwood.

The "Shore Protection" immediately above the bridge, on the Kansas side, commonly known as "Weaver's Dyke," marked 6 on the map, is built substantially of like materials, and in the same manner as breakwater 4, but it serves a different purpose It is about twelve hundred feet long, and lies nearly parallel with the general course of the river, crowding the channel gradually towards the east side It was built in water from twelve to fifteen feet deep, but an impinging current working on it during two months has undermined the outer edge and allowed it to sink, in some places to a depth of twenty-five feet without disturbing materially the height or line of the inner or shore side. The space between it and the Kansas shore has been filled with sand deposited by the water in the river, so that it is now dry at low water The distance from the lower end of this work to the east bank is a thousand feet, and I doubt the economy of building it any further into the channel until a spring flood shall have passed and indicated what is best to be done should more work be thought necessary.*

* March 5th, 1872 Breakwater 4 was finished, and the rip rap all put on the 16th ultimo, and "Weaver's Dyke" the day after The ice commenced moving in the river on the 21st, and broke up with a rise of nine feet above low water on the 23rd During the 23rd and 24th the ice ran with great rapidity and in large masses Much of it was sixteen inches in one thickness, and often two to four thicknesses had accumulated by one sliding upon another, until some of the masses measured five feet thick The ice did not go out with a continuous and uniform flow, but by successive gorges and breaks, the difference of level of the surface of the water being sometimes three feet in half a mile During the break up, breakwater 4 did not change position, but about two hundred feet of the lower end of 3 was lifted and brought down bodily, and now lies against the upper end of 4 On the 24th the ice gorged about three hundred feet below the end of 4, first against the east bank, the gorge extending westerly nearly across the river, causing the whole

I am confident that the next flood will furnish us with such experience as will enable us to successfully control the river from Belmont to the bridge line, so far as it may be in the interest of the Bridge Company to do so, for a sum not exceeding three-fourths of that estimated in my first report to you Considering the success and speed with which the work has progressed during the long and severe winter we have been laboring in, I know of nothing in the way of completing the work as at first contemplated

I see nothing to suggest an increase of any estimate made in my preliminary report

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On the Physical Characteristics of the Missouri River, and the means used for Directing and Controlling its Channel at St Joseph

1st September, 1872

When the headwaters of the Missouri River pass the city of St Joseph, they have travelled 2,500 miles, and are increased by all the streams flowing down the eastern slope of the Rocky Mountains between the thirty-ninth and fiftieth parallels of north latitude

The river at that point is the drainage of 418,000 square miles of watershed, upon which there is an annual rainfall of $19\frac{1}{2}$ inches

The elevation of low water in the Missouri River at St Joseph is stated by "Humphreys and Abbott" to be 756 feet above tide water The mean elevation of its surface is, therefore, 760 feet above the tide water It has about 480 miles further to go before joining the Upper Mississippi, near Alton, where it is 381 feet above the level of the sea Fourteen hundred miles above St Joseph, Captain Reynolds found the surface to be 2,194 feet above tide water

Its average slope, therefore, for about nineteen hundred miles, is

current to strike the head of "Weaver's Dyke" with such force, as in a few hours to cut a channel thirty four feet deep and undermine the face of the "Dyke" The Dyke "turned over" in the manner expected, and remained a complete breakwater, so far proving the ability of the materials used and the plan adopted to accomplish the desired purpose The channel opposite the east end of 4 is now six hundred and sixty feet wide, and the whole bar below the mouth of Blacksnake creek is rapidly becoming narrower by the washing of the current directed towards it by breakwater 4

The ice was hard enough and flowed with such force as to saw off, at the surface of the water, elm piles sixteen inches in diameter

ninety-six one-hundredths of a foot per mile, but the slope is not exactly uniform. Between eight hundred and a thousand miles above St Joseph, it is one and one-tenth feet, between four hundred and six hundred miles above, it is one foot, and from St Joseph to the Mississippi River it is seventy-nine one hundredths of a foot per mile

A careful survey for seven miles in the vicinity of St Joseph, and observations for a year, show an average slope of eighty-two one-hundredths of a foot per mile. The difference between the slopes of the river at these different points is so slight, compared with the great distances between them, that for any work of a local character the engineer may consider the average slope, as he finds it at any point above the confluence of the Mississippi and below Fort Union, to be a constant quantity, and hereafter in speaking of the river, I would be understood as referring to it in the vicinity of St Joseph

The distance between the bluffs of the Missouri in the vicinity of St Joseph is from four to six miles. They are generally rocky, composed of nearly horizontal strata of limestone, sandstone, soapstone and drift, and covered with a marl concretion sometimes called loess, supposed by some geologists to be identical with the loess bluffs of the Rhine upon which grow the famous vineyards. There are sometimes breaks in this rocky formation, the city of St Joseph is built in one about four miles wide, but the bluff is continuous, and a gap between the rock formation is generally filled with loess like that which caps the bluffs above and below. During the present geological and meteorological condition of the country, the wanderings of the river cannot extend beyond the bluffs

The valley between these boundaries is an alluvial plain, through which the river cuts its way from bluff to bluff, making eight complete crossings in a distance of thirty miles, measured in the direction of its general course. These windings of the river leave tongues of land alternately reaching from one bluff to within a few thousand feet of the other. Inhabitants of the towns built opposite the point of one of these tongues of land, have usually a constant fear lest some flood may cut through the base of the peninsula, letting the channel run along the opposite bluff thereby leaving them miles inland. Such cases have occurred within the last few years, one at Forest City, about twenty-five miles above, and one at Hamburg, near Nebraska City. These fears have a depressing influence upon any public work, depending for success upon the permanency of the

bottom lands The citizens of St Joseph are not without their fears, and although I do not say it is impossible that a cut-off should occur opposite the city, yet its improbability is so great, that for all practical purposes it may be considered impossible, and should the danger of a cut-off appear at any time imminent, the engineer can avert it

Without maps a particular description of the river and its windings may be necessary to an understanding of the matter, and here I may explain that all elevations given, refer to a datum line assumed one hundred feet below the surface of the flood of 1844, the highest known to civilized man This line is assumed to be 676 feet above the sea *

St Joseph is built upon the east side of the river valley, partly on the loess bluff and partly on the clay bottom lands, the largest part of which is above the reach of the highest floods Beginning three miles above the town, the river leaves a rocky bluff on the east side and runs nearly west across the valley to the rocky bluff at Belmont, thence, with a sharp curve, it returns to a loess bluff in the upper part of the town, called Prospect Hill, thence, with an easy curve to the south, with a radius of about 7,000 feet, it *now* flows along the clay bank in front of the town for about three miles, when, having acquired a due west course, it crosses the valley again and strikes the bluff above Palermo, about three and a half miles south of Belmont Thus the river has flowed about eighteen miles to accomplish seven of its general course

The channel at low water, which we find to be 80, is from three to five hundred feet wide, of very unequal depth, ranging from five to twenty-five feet, with an average sectional area of eighteen hundred feet, and a mean velocity of two and four-tenths miles per hour The exceedingly irregular character of the low water channel makes all measurements of this kind at such a time very unsatisfactory.

The following measurements were made under favorable circumstances, and I rely upon their correctness

At 86, the sectional area was 18,126 square feet, mean velocity, two and six-tenths per hour, discharge per second, 40,690 cubic feet At 92, the height of ordinary floods, the sectional area is 25,450 square feet; mean velocity, three and seventy-five one-hundredths miles per hour, discharge per second, 139,975 cubic feet At 92, the river is from fifteen hundred to thirty-five hundred feet wide between its proper

* *Vide* "Humphrey and Abbott"

banks When it subsides it leaves these banks distinct, but the space between them is nearly filled with sand-bars

The river at low water does not materially encroach upon the high water banks, but, first cutting its way through the lower bars, around accumulations of driftwood and the higher bars, it makes a channel which crosses the high water channel from bank to bank every two or three miles It then begins cutting away the higher bars, depositing lower ones along its own channel, and conducting itself, on a smaller scale, as did the larger river before it Sometimes it cuts its way through the base of a high bar and makes a new channel against the bank opposite to that along which it ran a few hours before, leaving the point of the bar an island

The bottom lands appear to me to have been built up in three different periods of time, each period depositing different materials, and under different circumstances from either of the others

Let us suppose the present time to belong to the third period In the second period, the river at average flood was from two to three miles wide, and had an average elevation of 100 Its highest floods must have reached 120, its low water channel was similar to the medium high water of to-day

In the first period, great floods filled the valley, and the river scoured its rocky bed with boulders weighing tons Its low water channel was greater than the greatest floods of to-day Its deposits were boulders, gravel, coarse sand and clay The high clay bottoms which exist to-day have this deposit for their source

The deposits of the second period were of fine sand and clay, and are of great fertility They are covered, when not cultivated, with a heavy growth of timber, principally sycamore, oak and elm, and some of the trees are of great size The deposits were made in the low water channel of the first period Their elevation is from 100 to 110

The deposits of the third period are silt and fine sand, having in them but a trace of clay and organic matter The silt and sand weigh from 61 to 86 ℔s. per cubic foot when dry and loose, and from 74 to 97 ℔s. dry and packed If not disturbed, in a few years they become covered with a thick growth of weeds, cottonwood and willows They are known as "cottonwood bottoms." A fact explaining the growth in height of the newer bottoms in some places is, that sand and silt brought up from the newer bars during the winter and spring months by the winds are

deposited among the weeds and brush A new bottom within two miles of St Joseph has grown five feet in many places within the last year from this cause The elevation of these bottoms is from 94 to 100

Now, the low water of to-day has very little effect upon the deposits of the second period, and the high water of to-day, equal to the low water of the second period, has small effect upon the deposits of the first The low water of to-day is continually cutting away and changing the form of the high water deposits, and the high water of to-day is annually disintegrating and destroying the deposits of the second period The low water of the first period sometimes cut through the base of bars making islands In the second period, whichever side of the island the river ran, the opposite channel was filled with its deposits, and it is through these deposits that a cut-off is possible for the floods of to-day The wanderings of the river of to-day are bounded, therefore, so far as cut-offs are concerned, by the deposits of the first period

In the tongue of land opposite St Joseph, at the east end of which the west abutment of the bridge now building across the Missouri River is placed, is a spine of this material extending from the rock bluffs at Wathena, between Belmont and Palermo, to within a mile and a half of the city Evidences of struggles and failures of the river in the second period to cut off this point are apparent in the direction of a steep bluff of the first deposits, five to eight feet high, dividing this from the second formation The land composing the tongue north of this spine is almost wholly of the second formation, while around the east end and along the south side, both the second and third are generally found

Although the general direction of the river bends may be considered fixed, yet among the lighter clay and sand of the second, and the light sand of the third deposits, occupying the low water channel of the old river, seldom less than two, and often three or four miles wide, the river wanders at will, and no spot therein can be considered a safe foundation for an enduring structure without artificial protection from its encroachments. To give such protection to the west approach to the bridge, and to insure the passage of the channel of the river through the draw at all times, were the ends sought to be gained by building dykes and shore protection last winter.

The bridge now building over the Missouri River at St. Joseph is located about a mile and a quarter below Prospect Hill, nearly in the centre of

the long bend in front of the city, and the embankment forming its west approach will rest for three-fourths of a mile upon a part of the third deposit At that distance from the river the approach reaches the first formation Every part of this space has been occupied by the river within the past fifty years At the time the location of the bridge was made, the channel of the river turned directly south from a point 1,200 feet west from Prospect Hill, and ran thence south to within half a mile of the bridge, at which point it impinged upon the Kansas shore, thence easterly, parallel with the bridge about 3,500 feet to the clay bank forming the east shore, leaving a bar a mile long and 2,000 feet wide, at an average elevation of 90, in front of the city, thence turning directly south, it formed the lower part of the long bend above referred to

The preliminary surveys for this work were made in February, 1871 The succeeding flood in June and July was small, enduring above 90 but eighteen days, and touching 93 only a few hours, but the action of the river on its west bank showed that in five years it would cut through the deposits of the last fifty years, and reach its old westerly shore, lengthening the bar in front of the city two miles, and leaving the bridge half a mile from its eastern beach

The problem was to stop the river where it was then running, and drive it three thousand feet east and through the bar and against the clay bank which was its eastern shore ten years ago Work was begun for this purpose in October last, and by the 1st of August following all of our objects were accomplished

The manner in which this work was done and the means used were as follows —

From a point on the west shore, three thousand feet southwesterly from Prospect Hill, a dyke was projected into the river at right angles with the current as it then ran, and continued in a right line eighteen hundred feet. This dyke inclines down-stream somewhat from a line at right angles with the general direction of a high water channel as corrected, the upper angle being about 70 degrees It is called "Beard's Dyke"

Again, from a point on the west shore, 800 feet above the bridge and 3,200 feet along the shore below Beard's Dyke, another dyke was built starting at an angle 45 degrees with the shore, and inclining down-stream, until at a distance of a hundred feet from the bridge it has an angle of 45 degrees with the general direction of the river, and is 1,100 feet from

the east shore This dyke is 1,200 feet long, and is called "Weaver's Dyke." The point where it leaves the shore is immediately above the point where the channel impinged upon the bank when returning, after having been turned aside by Beard's Dyke, half built, and except in one particular, which I shall hereafter mention, I am satisfied with the location of both dykes

The woodwork of Beard's Dyke is from sixty to seventy feet wide at the base, thirty feet wide at the top, and from twelve to thirty-six feet deep The lower side is vertical This woodwork is surmounted with a wall of rip-rap averaging twelve feet wide and three feet high, placed three feet from the lower edge of the woodwork, (*vide* sections, *Plate* XLVI) The whole was built to the average height of the bar on the opposite side of the river

It was known by extensive soundings that, along the site of the dyke, the bed rock had an elevation of from 35 to 40, and that on the top of the rock was a layer of boulders from five to seven feet thick, covered with a stratum of stiff clay from four to five feet thick, thence to bottom of channel, were the light sands of the river bed The top of the clay is about 35 feet below the surface at low water I am sure, from observations made while sinking the caissons for the piers of the bridge, that the river never scours through this layer of clay, although water soundings show that it often reaches it

Weaver's Dyke was built of like materials to Beard's Dyke, and over a similar foundation, but only to 82, except the one hundred and fifty feet nearest shore, which is built to 96. It was designed that this dyke should stop the action of the low water channel, and resist the efforts of the next flood to cut a deep channel on the west side of the river, after it should have been deflected to the west by the bar, as it surely would be after passing the east end of Beard's Dyke, yet the dyke was left low, so that too great an obstruction would not be offered at once, should an unusually high flood occur

Beard's Dyke was put and kept in position in the water while building, by first driving cottonwood piles about ten feet apart, within a space thirty feet wide along the lower half of the line of the proposed dyke. The piles were driven from ten to fifteen feet into the sand, left about three feet above water, and then sharpened at the upper end, so that they should not afford a foundation for the brush and timber to be put be-

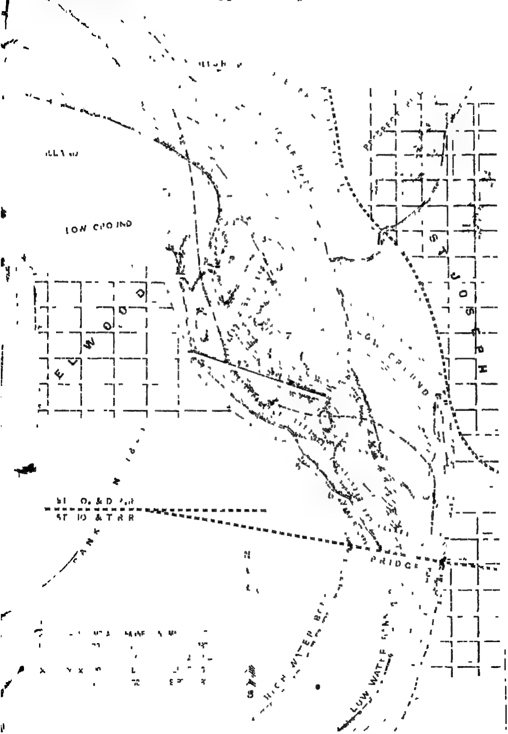
tween and upon them Then young cottonwood and sycamore trees, from sixty to seventy feet long untrimmed, were laid in parallel with the current, tops up-stream, until the mass touched bottom, when finer brush was laid on, and sand carted on from the shore sufficient to make a double road for teams This road of sand effectually packed and weighted the whole mass, and was kept high enough to allow the passage of horses and carts above the piles

The first channel crossed was five hundred feet wide, and when the work was begun, sixteen feet deep, with a velocity in the centre of four miles per hour, and no sloughs debouched from it on the east side for a distance of two thousand feet above When about half way across, the dyke obstructed the channel sufficiently to cause a difference of level in the water above and below it of three-tenths of a foot, and the increased velocity of the current consequent thereon, enabled it to scour the bottom to a depth of 26 feet The river also commenced cutting into the bar opposite, with a fair prospect of doing so as fast as we could build in so deep and rapid a current It showed me, however, that the dyke once down offered a greater resistance to the current than did the sandbars, and I permitted myself to have no doubts of final success on account of its failure thereafter The channel we were attempting to cross was the principal one of three, separated by islands of sandbars, the middle one was about seven hundred feet wide, but too shallow to be navigated by the ferry-boat at low water, and the last one was a mere slough, about three hundred feet wide, and was fast filling up

About two thousand feet above the dyke the west channel separated from the others. At that point it was about eight hundred feet wide, and six or seven feet at its deepest A dyke of a temporary character was built across its head, which turned nearly all its waters into the other channels, and greatly lessened the current at the main work, so much so that the washing away of the bar ahead of us ceased This temporary work was built of willow brush, laid between small piles driven with a wooden maul and weighted with a road of sand. It was about fourteen feet wide and eight hundred feet long, with its top about a foot above water Before it was completed the channel scoured the bottom in some places to a depth of from ten to eleven feet. In ten days' time it changed the navigable channel to the middle one, and remained intact until the breaking up of the ice in February following, when about half of it was

IRON BRIDGE OVER MISSOURI RIVER AT St. JOSEPH.

Map of the Missouri River, in the Vicinity of St Joseph, MO
showing changes in the channel, location of bridge, and position of breakwaters



torn loose and floated away A bar with its surface at 89 now covers the remainder Until after a rise of two feet in November, which nearly filled the channel behind it with sand, it withstood the pressure of a head of water four-tenths of a foot high

After this dyke had succeeded in turning the channel, Beard's Dyke was completed in the manner in which it was begun, and across the channel to an island about four hundred feet wide, with a surface of 82 Over the island, which was but a sandbar, the dyke was built without piles Upon reaching the river again, the dyke behind us was built to 88, the rip-rap wall put on, and a sand road made upon it, by which to bring forward material The river was now frozen over and the current quite sluggish The middle channel was crossed with the dyke without having to work in a greater depth than fourteen feet A narrow bar between the middle and east channels, two feet under water, was reached, and the east end of the dyke was finished by building a mole about one hundred feet in diameter at the bottom This was built by driving eighty piles within the limit of its base, and piling up between and upon them brush with the tops outward, in layers alternating with rip-rap, to the height of the dyke The layers of brush were about four feet thick, and of rip-rap two Upon the top of this work a mound of rip-rap was built to 93. Although the river has scoured to a depth of 35 feet on the upper and east sides of the mole, its total settlement since completion is less than six inches.

By the time this work was completed, a deep channel, 490 feet wide, had cut through the east channel or slough before-mentioned, and had for its east shore the wide bar in front of the town It was deflected by the bar to the west, and, reaching across the old channel, struck Weaver's Dyke nearly at right angles at a point but a few feet from the shore end Weaver's Dyke, built in the same manner as Beard's Dyke, of piles, brush, sand and rip-rap, had for its principal object the affording of resistance to this expected attack of the river upon the west shore The dykes were built in the form and manner described, upon the hypothesis that should an impinging current scour the bottom and undermine the front of the dyke, the front part would settle and sink down until the lowest limit of scour was reached, the back part remaining without material change of elevation The front of Weaver's Dyke was built in from ten to fifteen feet of water. When the channel from the end of

Beard's Dyke struck it, as before-mentioned, it began scouring and letting down the front as expected The point of impingement of the current gradually passed down-stream along the face of the dyke, and before the ice broke up the whole front of the dyke had reached a depth averaging eighteen feet below low water

These dykes were finished about the middle of February The river was then frozen over with ice from twelve to sixteen inches thick, with a surface at 82½ The ice showed signs of breaking up about the 20th of February, and on the 23rd it started, the river suddenly rising to 87 This soon cut a channel 650 feet wide opposite the east end of Beard's Dyke. The channel appeared a river of rolling ice, scarcely any water being visible Large masses were forced against and entirely over Beard's Dyke, without injuring the wall of stone or moving any part of it Weaver's Dyke being low, much ice escaped over it in from four to five feet of water

On the 24th a gorge of ice formed about four hundred feet below the east end of Beard's Dyke, extending from the east shore of the river to Weaver's Dyke The gorge dammed the river until it stood three feet higher above it than at the bridge, distant about half a mile below The gorge broke first at Weaver's Dyke, and in a few minutes the channel was scoured to such a depth that it remained from thirty to thirty-four feet deep along the face of the dyke after the ice was gone and soundings could be made with the river at 84 The dyke settled down in front with the scour—turned over, so to speak—but the wall of rip-rap remained at nearly the same height and in the line where it was built. Beard's Dyke across the middle channel settled about two feet This is probably as severe a test of the ability of this form of dyke to resist and turn aside the river as could be afforded under any circumstances.

About the 1st of June this year, the spring-flood had reached 90, almost entirely submerging the great bar, and flowing over Beard's Dyke in a thin sheet, with a fall of from six to eleven inches And now began in earnest the work of removing the bar and making a new channel along the clay bank of the east shore. To do this required the taking away of at least five million cubic yards of sand This was accomplished by the middle of July, the flood averaging 93 meantime

The effect of the obstruction to the current by Beard's Dyke at this height of the river was to make a lake of comparatively still water above it, extending to the current of the flood then running along the bar

opposite Prospect Hill. Through this lake ran threads of current to supply the overflow of the dyke, strong enough to move sand along but not to scour. The dyke standing firm, this lake was a constant force pressing the current against the bar. Thus the current attacked first near Prospect Hill, by eating into it abruptly fifty to a hundred feet, forming what is called by river men a "pocket." The pocket once formed, it moved down-stream, the current cutting away the bar as the mower cuts a swath, and in a few days would pass below the dyke and disappear. But before the first one had done its work, the second and sometimes the third had begun, and were following swiftly after. Meanwhile sand was deposited along the line between the still water and the current, and as the bar disappeared the current still pressed against it, crowded by the still water—the line of deposit passed eastward, the new formed bar widened and became the west boundary of the channel. This continued until the current met the resistance offered by breakwaters constructed by M. Jeff Thompson, thirteen years ago, and still remaining effective along the east bank. It was then where it was wanted.

I have said the pockets disappeared after passing below the end of Beard's Dyke. The river there was thirty-five hundred feet wide, while at the bridge it is but fourteen hundred, with the width in which it was possible to scour narrowed by Weaver's Dyke to less than eleven hundred, and in this space stood a pier twelve feet, and a draw-rest thirty feet wide. The great quantity of sand taken away by the river above Beard's Dyke must, therefore, be deposited in the still water behind it, or be carried through the narrower space at the bridge. For some weeks after the flood was at 93, the channel below Beard's Dyke was very uncertain. Every pocket that came down from above made changes in the direction of the current, which sometimes struggled over the lower end of the bar and through the bridge, and again rushed westward over Weaver's Dyke to the west shore. The amount of sand brought down was more than it could at once dispose of, and a sand gorge formed opposite Weaver's Dyke, which changed the slope of the river in half a mile from five inches to nine. Thus the whole channel was caught in a great pocket with Weaver's Dyke on one side, the clay banks on the other, and a sand gorge at the bridge in front. This gorge disappeared wholly about four weeks after the formation of the great pocket, and the channel became uniform and along the east bank of the river. The line between the still water above Weaver's and

below Beard's Dyke, and the current became defined, the sand deposits along this line began, and, at this writing, with the water at 87, the west boundary of the channel is as regular as the east, and is defined by a bar out of water nearly all the way from a mile above Beard's Dyke to the bridge

Whenever the surface current was forced over Weaver's Dyke by the sand gorges in the channel, the direction taken approximated to a line at right angles with the dyke, therefore it impinged upon the west bank immediately in the rear of the dyke The effect of this impingement was to form whirlpools about two hundred feet in diameter between the dyke and the bank, the outer rim running at the rate of ten miles per hour, the vortex two to two and a half feet lower than the rim These whirlpools often developed themselves fully in fifteen minutes from their beginning, and would cut away the bank at the rate of thirty feet in twenty minutes They often became in half an hour so full of drift wood, that the water was scarcely visible Their action upon the bank was stopped by a revetment of trees brush and rip-rap, followed by a double line of piles driven parallel with the shore and about a hundred feet from it When the sand gorges in the channel gave way, these whirlpools ceased as quickly as they began, and the driftwood floated away down the river Soundings taken over the space where they existed immediately after their disappearance, showed that they scoured to the surface of the clay stratum at an elevation of 45 The dyke remains as it was built Had Weaver's Dyke been placed at right angles with the current, these whirlpools could not have formed, and in completing the system of dykes at the west approach, the bank of the approach will be made the high water dyke, and a low water dyke will be built to 82 directly along the bridge line, six hundred feet out from the west abutment, thereby leaving Weaver's Dyke to act simply as a revetment for the west shore above the bridge

The influence of Beard's Dyke is such that for a mile above it, and west of a line parallel to the present channel and passing five hundred feet to the east of it, there is no channel with the water at 87 for a boat drawing three feet, while in many places, and particularly in the deepest of the channels obstructed by it, the sand has filled in forty feet deep, and now completely covers the dyke from sight The surface of the new bar is in many places at 91 Below the dyke, sand and mud have

been deposited, so that with the river at 82, there will be a bar a mile and a half long and half a mile wide, where flowed the river eight months ago The amount of deposits caused by this dyke during the flood of this summer is more than 8,000,000 cubic yards The bulk of the dyke as it now stands is 56,000 cubic yards, of which 3,000 cubic yards is rip-rap, and the rest brush and trees, with the interstices filled with sand Its cost, including engineering and superintendence, was $32,600, and it was built in four months' time

Weaver's Dyke was built at right angles to the line it was expected the current would take after being disturbed by Beard's Dyke, and for the purpose of resisting the current until Beard's Dyke, should have caused the channel to run along the east shore, and entirely away from it Had it been built perpendicular to the channel at the time it was commenced, it would have failed to protect the shore, as the new channel would have run parallel with it

It was not expected that one flood would accomplish all that was desired, but the extraordinary duration of the flood this summer—about 90 for ten weeks—enabled the river to do as much as was expected of it in two ordinary seasons I think more water has passed this summer than during the great flood of 1844, which, although six feet higher than the river has been this year, was of short duration The water now averages four feet above that at the same time in any year of which we have any record, and it is still so high above low water, that the whole effect of the works cannot be seen with the eye, but is only known by careful soundings

I have endeavoured in this paper to state as briefly as possible the purpose for which the works were built, the surrounding circumstances, and the results already attained, and although in my own mind I am satisfied that our success is complete, I purposely avoid suggesting theories or drawing conclusions until the present flood shall have subsided and shown exactly what has been accomplished.

E. D. M

No CCIV

RAILWAY IN JOHORE

By H. Vacher, Esq , *Exec Engineer, P W Dept , Johore*

Dated 30th March, 1876

The Independent Territory of Johore, consisting of some 20,000 square miles of the southern portion of the Malay Peninsula, covered with dense virgin forests of more or less valuable timber, is rapidly becoming colonized by the influx of Chinamen, who clear away small portions of the forest to form gambier and pepper plantations, and settle here under the protection and encouragement of the present Maharajah The revenue of the country is derived almost entirely from these Chinese settlers a tax being levied on all produce exported from, and on the opium and spirits imported into, the country The plantations are now increasing very much in size and number, and the primitive method of transporting the produce is yearly creating greater difficulties to the planters The Chinamen indeed are refusing to take up more land, especially as they have to go further and further into the interior, unless proper roads are made for them at the Maharajah's expense

Rough bridle paths cut through the forest from the banks of the rivers, being the only present means of approach to the plantations, the whole of the produce has to be carried on the backs of coolies (in many cases a distance of seven or eight miles) to the nearest river, where it is shipped in small boats drawing but little water, and conveyed thus to the coast, where it is again transhipped into larger boats, and brought round either to the town of Johore or that of Singapore

After a few days rain, these small paths, from the slippery nature of the surface soil and the absence of any attempt at drainage, are almost

impassable, the rivers too, which are narrow and rapid, become on these occasions so swollen, that it is with great difficulty the little boats can be navigated down-stream safely. It has become therefore absolutely necessary for the progress of the country, that proper roads of some kind or another should be constructed without further delay. Unfortunately there is no stone, for ballast, to be obtained in the country, and as already mentioned, the surface soil is soft and slippery, and the few roads that are round the town of Johore (the capital of the territory) are terribly cut up by bullock cart traffic, after two or three days rain. The only means of procuring ballast, would be either to import stone from one or other of the adjacent islands, or to make artificial ballast by burning the clay to be found in the country, but both these methods would be very expensive. A further difficulty in the way of transport arises from the fact that there are very few cattle in the interior, and moreover very little grass or other plant growing without cultivation, upon which they can be fed. No cattle will eat the rank coarse grass, known here by the name of "callang," which rapidly covers all ground cleared of the primeval jungle.

To meet these combined difficulties, the first idea that suggested itself for opening up the country, was that of a light iron railway, laid without ballast, and to be traversed by a wood burning locomotive, and it was to the carrying out of this scheme that I first applied myself. Unfortunately I was obliged to abandon the idea of using iron rails, on account of their cost, and wooden rails was the alternative, on which I had to fall back. I then decided to make a trial mile by way of experiment, arranging that the first portion of the line should commence at the town, running in a north westerly direction, and planned ultimately to skirt most of the larger plantations, and terminate at the foot of a small mountain about 3000 feet high, a distance altogether of about twenty miles. This mountain and the elevated ground surrounding it, is thought to be very valuable for special plantations. The hill would also make a good sanitarium. I should here state that, some years ago a wooden line had already been laid down in Johore for some miles, though it had never been of any use, principally on account of the ground not having been properly surveyed. The sharp irregular curves and the wonderfully steep gradients, would alone have effectually prevented any locomotive from ever traversing it, apart from the fact that no attempt had been made to drain the

banks and cuttings, the former passed over several mangrove swamps consisting chiefly of old trees filled in with bad earth, and the latter through some very steep hills, the cuttings of which being almost vertical, were constantly falling in. This line had long ago been set down as a failure, and of no value for any permanent purpose. But after giving the matter my most careful consideration, and procuring all the information I could, relative to existing wooden railways in Canada and elsewhere, I came to the conclusion that, if properly constructed, a wooden line was at least feasible.

After a variety of experiments, in order to ascertain the best form and method of laying down the rails, a trial mile was completed, and one of Dub's light bogie engines (kindly made over to His Highness by the Indian Government) was placed on the track.

This locomotive ran remarkably smoothly, at a speed of about ten miles an hour, on the wooden rails, without breaking or bending them, or even abrading the wood in ever so slight a degree, and, I believe, the trial was considered by Sir Andrew Clarke and others who were present upon the occasion, so far, a decided success. The same engine has since run over this portion of the line about a hundred times, carrying materials, &c., and the rails at present certainly do not look much the worse for wear.

The rails and sleepers are made of Johore teak, (a hard close-grained wood, not liable to dry rot or to be attacked by white ants, known here by the name of "Ballow"), and the former are secured to the latter by means of wedges and trenails of the same materials. I am also constructing all buildings and station machinery, bridges, and culverts, and roofs (up to thirty feet span) in the same manner, entirely without iron in any form or shape whatever, so that the whole railway throughout, will be made solely of wood cut from the forest, and built or laid on the natural soil of the country.

I am now completing the survey of the projected line to the foot of the mountain already alluded to, and pushing on with the earthwork and culverts as fast as the means at my disposal will permit, I have promised to send estimates and drawings, together with all necessary information, to Sir Andrew Clarke, so soon as the first portion of the line is actually open for traffic, and we are fully assured of its success.

H. V.

No CCV

STONEY'S CONCRETE-MIXING MACHINE

[*Vide* Plate XLVIII]

On the Manufacture of Portland Cement, and of Concrete and Mortar.
By Bindon B Stoney, Esq, M A, *M Inst C E*

December 1871

Of the various inventions which have been made in the arts of Construction within the last half century, there are few that can compete in importance or extensive application with Portland cement, so named from its resemblance to the well known Portland stone For this invention we are indebted to a bricklayer of Leeds, in Yorkshire, named Joseph Aspdin, who took out a patent for artificial stone on the 21st of October, 1824, which he thus describes —

"My method of making a cement or artificial stone, for stuccoing buildings, waterworks, cisterns, or other purpose to which it may be applicable (and which I call Portland cement) is as follows —I take a specific quantity of limestone, such as that generally used for making or repairing roads, and I take it from the roads after it is reduced to a puddle or powder, but if I cannot procure a sufficient quantity of the above from the roads, I obtain the limestone itself, and I cause the puddle or powder, or the limestone, as the case may be, to be calcined I then take a specific quantity of argillaceous earth or clay, and mix them with water to a state approaching impalpability, either by manual labor or machinery After this proceeding, I put the above mixture into a slip pan for evaporating, either by the heat of the sun or by submitting it to the action of fire, or steam conveyed under, or near the pan, till the water is entirely evaporated Then I break the said mixture into suitable lumps

and calcine them in a furnace similar to a lime kiln till the carbonic acid is entirely expelled The mixture so calcined is to be ground, beat, or rolled to a fine powder, and is then in a fit state for making cement or artificial stone The powder is to be mixed with a sufficient quantity of water to bring it into the consistency of mortar, and thus applied to the purposes wanted "

The characteristic of Aspdin's invention is, that lime and argillaceous clay, both in a state of very minute division, are intimately mixed together in certain proportions, then dried and calcined, and finally ground to powder Aspdin, however, working with the materials at his disposal, calcined the lime in order to reduce it to a sufficiently divided state before adding the clay, whereas the ordinary Portland cement of commerce is now made of chalk and clay, and as the chalk can be reduced to a fine powder without previous calcination, the expense of double firing is saved, and the manufacture much simplified Besides the artificial Portland cement (manufactured in Great Britain, chiefly on the banks of the Thames and Medway, where the raw materials are abundant) there are natural cements, *largely manufactured from natural marls containing about 30 per cent* of clay, in which the combination of calcareous matter and clay is apparently more perfect than in the artificial mixture, and might therefore, perhaps, lead us to expect better results With very few (if any) exceptions, however, the best class of artificial Portland cement is stronger than that made from natural marls, perhaps from the composition of the latter being variable, or from some more obscure cause—and the author therefore confines his observations to the artificial cement made of chalk and clay

There are two methods of making artificial Portland cement, namely, the wet and the dry method, in the former the ingredients are mixed with the aid of water, in the latter without water The wet method is that adopted in England The dry method has been tried on the Continent, but with what results the author is unable to state

The first process in the manufacture of artificial Portland cement by the wet method consists in the due mixture of the clay and chalk, which is generally effected in a circular wash-mill shaped like a huge tub, with a central upright axis to which are attached horizontal arms carrying vertical knives, the rotation of which stirs up and incorporates the materials

operation is probably the most important one in the whole manufacture, as the success of the result mainly depends on the care taken in duly proportioning and thoroughly incorporating the chalk and clay in a very finely-divided state The usual proportions are from 3 to 4 parts of chalk (according as it is the white or grey chalk), with one of clay, by measure, and both ingredients should be as free as possible from sand or vegetable matter The clay should be the alluvial clay of lakes or rivers, in a state of minute division, and long exposure to the air should be avoided, as this has been found to injure its quality for artificial cement

From the wash-mill the creamy mixture flows into tanks or reservoirs in the open air, which have an area of several hundred square feet and are about one yard deep Here the washed stuff is precipitated, and the clear water allowed to run off through suitable sluices, leaving a pasty mixture, which, after being partially air-dried, is cut into lumps and wheeled to the drying ovens, from which again it passes to the kilns, which are of a circular form, somewhat resembling an ordinary lime kiln, and worked on the intermittent principle with coke fuel Here again much attention is required, for if the washed material has too large a proportion of clay, a smaller quantity of fuel is required, and it is to be feared that this tempts some manufacturers to overdose with clay, which generally produces a quick-setting, but weak, cement On the other hand, it is scarcely possible to overburn cement in which the proportion of lime is excessive An excess of lime, however, renders the cement (especially if fresh from the manufacturer,) liable to crack—no doubt from the free quicklime throughout the mass swelling subsequently to the process of setting For this reason it is generally advantageous for engineering works to keep the cement some months in store before using it, though plasterers are said to prefer the fresh and quicker-setting cement

The temperature of calcination should be very high, so that the cement may agglutinate and arrive at the limit of vitrification. In this respect the calcination of Portland cement differs essentially from that of Roman and some other natural cements which are injured by being brought to the verge of vitrification Some writers think that the sole duty of the kiln is to expel the carbonic acid from the mixture of argillaceous matter and lime, there can be little doubt, however, that the chemical combination of the lime, alumina and silex is partially effected in the dry way during the burning, and that it is subsequently carried on and completed by the

agency of water, and if this be the case, the analysis of a cement stone after calcination should show the commencement of this process, by the presence of silicates of lime and alumina. It should, however, be kept in view that a most essential condition of the paste in the reservoirs is that its composition be quite homogeneous, otherwise the portions richest in silex would fuse and form silicates which could not enter into combination with water, and this agrees with the fact that the state of incipient vitrification appears to be the proper limit of calcination. Highly burnt cement is denser than ordinary cement, and density is almost invariably an indication of strength. First-quality cement must therefore be highly burnt, but as the extra cost of the fuel is not more than one to two shillings per ton of cement, this should be no obstacle to its production when cement of high tensile strength is required, equal to engineer's test. The produce of the kiln, when made from properly mixed materials and carefully burnt, will be a clinker of a dark greenish-black colour, and reduced to about one-half the original weight. Sometimes a large proportion of dust is formed along with the semi-vitrified clinker, this dust, when mixed with water, will be of a bad colour and deficient in tensile strength.

When sufficiently cool, the contents of the kiln are crushed and reduced to small lumps and finally ground between horizontal stones, like those used for grinding corn. If the cement is not ground sufficiently fine, there will be a large percentage—in many cases far exceeding 10 per cent—of coarse unground particles, which are inert in the making of mortar, and act apparently like so much additional sand. This hard granular portion, if finely ground, will set like the rest. It is probably the very cream of the cement, as it will bear a high tensile test if ground fine. In the granular form, however, it does not set, and counts therefore for nothing as cement, and is so much waste to the consumer, who thus loses a portion, which the author has not accurately ascertained, but believes considerably to exceed 10 out of every 100 tons which he buys from the manufacturer. Far too little attention has been paid to this matter of pulverization, for not only is the loss in weight very serious in itself, but this useless portion is the heaviest, and probably therefore most valuable of all the cement. In America, the usual practice seems to be to grind their cement much finer than in England, so much so that not more than 8 per cent of a cement should be rejected by a sieve of 6,400 meshes

to the square inch. It is probable, however, that the American cements, produced from natural cement stone, are more easily ground than artificial English Portland cement.

To enumerate briefly the properties of Portland cement. Its colour is a stone grey with occasionally a slightly greenish tinge. Buff-coloured cement is almost invariably weak, and owes its colour probably to an excess of clay or to imperfect burning. The density of Portland cement in powder varies from 1.2 to 1.4. It sets slowly, and contracts nearly 30 per cent. when mixed with water. The lime is always in excess, and the following analysis by M. Bouniceau represents the chemical composition of cement manufactured by one of the leading London firms:—

Silica,	20.84
Alumina and oxide of iron,	12.75
Lime, free, or combined with some carbonic acid,	4.05
Lime in combination,	60.47
Sulphate of lime,	1.89
	100.00

The composition varies slightly, and the silica may reach 24, and the lime in combination diminish to 54, per cent. We may, however, generally assume that London Portland cement contains about 65 per cent. of lime and 20 of silica, and that the remainder is chiefly alumina; it also contains a little oxide of iron, magnesia, and sometimes 3 per cent. of alkalies. Indeed it is probable that all cements contain some soda and potash, derived from the argillaceous matter.

Portland cement is especially valuable in engineering operations, as it is less hygrometric, and it will keep longer and bear transport better than other cements. It hardens either in air or in water, and it resists frost and atmospheric changes well. Even after being partially set, it may be worked up again, though the practice is not recommended, and as it takes long to set when made into mortar, it does not require any peculiar skill on the part of the workmen. It bears a far larger burden of sand than hydraulic lime or Roman cement, and even when much dearer per ton than the former, it will frequently be found cheaper in reality, as it may be mixed with from two to three times as much sand. It is extensively applied to architectural ornamentation, and many of the finest modern dwelling-houses in the west end of London owe their handsome appearance to Portland cement stucco. The shipbuilder, too, largely avails himself of Portland cement for plastering the inside of the bottoms of iron ships,

whereby bilge water, dirt, ashes and other corroding matters are prevented from coming into contact with the iron. In addition to its density, Portland cement is usually tested by tearing asunder small bricks of an I shape—the section at the centre being $1\frac{1}{2}$ inch square, that is, the area equals $2\frac{1}{4}$ square inches. The standard which the author requires is, that the cement shall weigh 112 lbs. per bushel, equal to $87\frac{1}{4}$ lbs. per cubic foot, in the dry uncompressed state of powder, and that its tensile strength shall not be less than 350 lbs. per square inch of section after seven days' immersion.*

MANUFACTURE OF CONCRETE AND MORTAR.

We shall now proceed to consider some of the ways in which cement is used, and first and foremost, concrete demands our attention. To understand the qualities of concrete, we should bear in mind that mortar is a mixture of lime or cement with sand, while concrete is a mixture of lime or cement with gravel, or with broken stone and sand; and as gravel is composed of sand and pebbles intermixed, we may make concrete by mixing common mortar with pebbles or broken stone; and this method is sometimes adopted, though it has the disadvantage of requiring somewhat more manipulation than the ordinary plan of mixing all the ingredients in the dry state first, and then tempering them with water. Regarding concrete, however, in the aspect of common mortar mixed with pebbles, we get an adequate conception of its properties. It is, in fact, rubble masonry, the stones of which are much smaller than in ordinary rubble work, and the theoretic mode of making concrete would be to take a box full of pebbles or small stones and fill in all the voids with mortar. If we carry this idea out further, we may view mortar as a mass of sand, *i. e.*, very small stones, with all the interstices filled up by lime or cement paste. Practically, we require a larger proportion of mortar for concrete, and of lime or cement paste for mortar, than this theoretic view of the matter requires, for it is important that each pebble or grain of sand should be completely coated with a layer of the cementing material, and to ensure this and make amends for irregular distribution of the ingredients, we put in a greater proportion of the finer materials than theory demands. Concrete may vary in quality from coarse mortar to small

*The reader will find much useful information on limes and cements in Gilmore's "Practical Treatise on Limes, Hydraulic Cements and Mortars," and in Reid on the "Manufacture of Portland Cement

rubble, the quality being generally determined by locality and the greater or less facility of obtaining suitable coarse ballast, as well as by the nature of the work, but whether the ballast be fine or coarse, it is very essential that it be free from loam and organic matter

Where machinery is not used for the manufacture of concrete, the author finds the following the most suitable method of ensuring the proper proportions and careful mixture of the ingredients The ballast is barrowed into a tray of rough deals without ends, generally of the following dimensions —length 20 feet, breadth 6 feet, height of sides from 2 to 4 feet When the tray is filled with ballast, a straight edge is passed along its top sides, so as to reduce all the ballast to the same level as the tray, and battens of definite thickness are then laid on the top sides to gauge the due proportion of cement, which is spread above the ballast—its surface being levelled with the straight edge as before, so as to agree with the upper surface of the battens Thus, if the tray be 3 feet high and the battens 6 inches deep, the proportion of cement to ballast will be 6 to 1, if the battens be 4½ inches deep, 8 to 1, and so on Two men then face each other at one end of the tray, and turn its contents over from end to end, thrusting their shovels along the floor of the tray By this arrangement the ingredients are mixed in the dry state with tolerable uniformity, and the men begin again at either end, incorporating the mixture with water thrown on from a bucket by a third man, in the same manner as mortar is mixed by hand In some cases where time presses, the two first men, after gauging the concrete roughly with water, pass it on to two other men, who give it another tossing and then throw it into the foundation pit or wherever it may be used, and here it is chopped with a shovel and tamped to make it lie close, or (what is found to answer exceedingly well) a man with heavy boots treads on it, so as to compress it and squeeze out superfluous water which rises to the surface and flows off

Besides good materials, two things are requisite to make good concrete 1*st*, Water should not be used too freely, and this requires careful supervision, for a large addition of water diminishes the labor of turning over the stiff mass, and therefore there is a great temptation to the workmen to use more than is necessary 2*nd*, The ingredients should be very thoroughly incorporated, so as to make a homogeneous mass, and this (being very hard work) is apt to be badly done unless the laborers are

very carefully watched On this account machinery is preferable to hand labor, and several concrete mills have been invented One of these, which the author devised some years since and has used with very great success indifferently as a concrete or a mortar mill, may be described *Plate* XLVIII represents this machine It consists of an open trough made of cast or wrought-iron, 7 to 8 feet long, and $3\frac{1}{2}$ feet wide The lower portion is semi-circular in cross section, and the sides above are slightly splayed outwards Through the centre of the trough passes a wrought-iron shaft, $3\frac{1}{2}$ inches square, in which adjustable blades of wrought-iron are inserted, the blades being so arranged that they may have a tendency to screw the concrete forward as the shaft revolves This can be adjusted at will by turning the blades on their axes, so as to increase or diminish their pitch The travelling movement is also accelerated by inclining the trough in the direction of its length, so that it may have a fall or slope downwards towards the delivery end The motion may be communicated either by a belt or gearing from a 3 H P engine The method of working is as follows —The gravel and cement are gauged in their proper proportions as already described, in a tray alongside, and two or four men shovel them, without further mixing, into the upper end of the mill, where the first three or four blades toss over and incorporate them thoroughly in the dry state Water is gradually let on from a rose placed about one-third of the length of the trough from the upper end, and from that to the delivery end the mixture of the three ingredients—gravel, cement, and water—is perfected, so that the mortar or concrete as it comes out is quite uniform in colour, and the mass homogeneous in appearance The result is exceedingly satisfactory, the machinery is of the simplest character, all the operations are open to view, and the friction is far less than in the ordinary pug mill As the ends of the blades wear down after several months' use and become shorter, a small interval is left all round between them and the inside of the trough This becomes filled with mortar, which sets hard and forms a lining to the trough, preserving the latter from wear, and when the ends of the blades are renewed after several months' use—which is simply effected by welding a short piece of iron or steel to the ends, so as to bring them to their original length—the coating of mortar is readily chipped off, and the trough restored to its original condition The great advantage of this machine over hand labor consists in the facility of mixing the ingredients thoroughly and with a

small amount of water It never flags, and requires little watching, whereas laborers are apt to add an excess of water to relieve the labor of turning over the tough mass, or they add water in irregular quantities, and unless very carefully looked after, the mixture will be imperfectly made, and the mass resemble half-tempered mortar Other machines have been applied to the manufacture of concrete—such as revolving cylinders, inside which the concrete is tumbled about till it gradually works its way to the lower end, and curiously constructed boxes, into which the dry materials are first thrown through a door and afterwards sluiced with water, when after a certain number of revolutions the box is opened and the concrete taken out The author has not used this latter machine, but from its operation being so frequently interrupted and so much time being lost in filling and emptying it, it must necessarily be less economical than the horizontal mill, in which the action is continuous without any interruption

As already stated, this concrete mill is equally efficient for making mortar Indeed the author ventures to think it far preferable to any of the ordinary mortar mills, especially the pan with edge runners, which tend to grind and triturate the sand, thus reducing its sharpness and doing useless work In the manufacture of hydraulic mortars, the correct mode of procedure seems to be (1), To have the lime or cement finely ground, (2), To incorporate the sand and lime in the dry state, (3), To temper the mixed materials as rapidly as may be with a moderate amount of water When the lime is not previously ground, and when therefore lumps occasionally occur in it, the edge runners have the merit of crushing these lumps, and thus rendering the mortar homogeneous. In this case only does the runner mill seem to present any advantage over the horizontal mill, while the latter is far simpler, cheaper, and more rapid in its operation, as when properly served, it is capable of turning out as much as 10 to 12 cubic yards of concrete or mortar per hour

B. B S

Note by EDWARD W STONEY, ESQ, *M Inst C.E, Chief Engineer's Office, Madras Railway.*

Madras, May 1876

The above paper on Portland Cement by B. B Stoney, M A, M Inst C E, contains drawings and descriptions of a most simple and efficient concrete mixer, which could be easily manufactured out here in India.

These machines have been regularly used for several years on the Port of Dublin Works, where very extensive concrete works are being done, and I have seen them at work,—they are so simple, open to view, &c., that they give no trouble and work beautifully.

This description should be of considerable interest and use to Engineers engaged in concrete works in this country.

The machine could be driven by bullock gear for small works.

E. W. S.

No CCVI

CONSTRUCTION OF LIGHTNING CONDUCTORS

By Dr R J Mann, M D, F R A S

[*Read before the Meteorological Society, 9th May, 1875*]

There are certain principles bearing practically upon the efficient protection of buildings from injury by lightning, which are well ascertained, and which are now looked upon as established facts in electrical science Thus, for instance, it is well known that the primary aim of the Architect or Engineer who attaches a lightning conductor to any building, is to furnish a path for the electrical discharge that shall afford the least possible resistance to its passage, or, in another form of expression, a ready way for the escape of the pent-up force This end is gained—first, by employing a metal that is in itself a good conductor of electrical action, and secondly, by taking care that the dimension of the metallic conductor, whether it has the form of strip, rod, or rope, is ample for the work that it has to do; that there is large and free communication between it and the earth, which is the great electrical reservoir of nature, and that there is no break of metallic continuity, no obstruction to the free and unimpeded movement of the discharge anywhere

When the question of the character and size of the lightning rod, which may be expected to fulfil these conditions satisfactorily, was examined by the French electricians in the year 1823, and still more recently in 1854, it was held that a quadrangular iron bar, three-quarters of an inch in diameter, was sufficient in conducting power for all purposes Since that time, ropes of metallic wire have pretty well superseded the employment of solid bars, on account of the greater facility with which they can be applied to objects of irregular form, and on account of the readiness with

which they can be constructed, in unbroken continuity, to any length. Copper is also very generally used in preference to iron, because of its superior transmitting power, and of its greater immunity from corrosive oxidation when exposed in moist air. In reality, however, the selection of iron or copper is not of material importance, if the surface, in the case where iron is employed, be protected from oxidation by a coating of zinc, and if the size of the rope or bar be sufficiently great to compensate for the inferiority of its transmitting power. That is to say, a large rope or bar of iron conducts quite as freely and well as a small rope or bar of copper. Copper is about five times as good a conductor of electrical force as iron, an iron rope or rod, to perform the same work, should, therefore, have at least a sectional area five times as large as a copper rod or rope. It must, however, always be borne in mind that the resistance of a metal conductor increases with its length, and that, therefore, for the protection of lofty buildings, larger ropes or rods are required than need be employed for lower structures. The facility of electrical transmission in any conductor is practically in the exact ratio of the coefficient of the conductibility of the metal, multiplied by the section of the rod, and divided by its length.

The French electricians of the present day adopt copper wire ropes of from four-tenths to eight-tenths of an inch for each 82 feet of height. Mons. R. Francisque Michel, who is at the present time the scientific adviser of the French Governmental Department of works in such matters, seems to consider a rope of galvanized iron wire, eight-tenths of an inch in diameter, to be ample for most purposes. Mr. Faulkner, of Manchester, has recently used in the protection of St. Paul's Cathedral, which, even within the last three years, was found to be in very faulty state in regard to its safety from lightning, a copper wire rope, half an inch in diameter, which is made of eight strands of one-tenth of an inch copper wire coiled round a core of seven smaller copper wires of about one-half that diameter. This copper rope weighs six ounces and three-quarters to the foot. Eight of these ropes, in the case of St. Paul's, have been brought down from the golden cross, which surmounts the dome, to the ground: the element of great height in this instance has, therefore, been amply provided for.

Mr. Faulkner frequently uses, for the connection of large iron pillars and other metallic masses in large factories, and for earth-contacts with the pillars, large bands of solid copper of No. 11 Birmingham iron wire

gauge, and four inches broad, and which weigh 1 lb 13 ounces to the foot Messrs Sanderson and Proctor, of Huddersfield, manufacture a very convenient kind of copper tape for lightning conductors, which is three-quarters of an inch wide, and an eighth of an inch thick, which has even more flexibility than wire rope, and which can be made in continuous stretches of great length with equal facility Strips have the advantage over rope in one particular They are free from the strain which is prone to be set up in the molecular condition of rope under the operation of twisting Mr Gray, of Limehouse, refers to some instances in which copper rope has seemed to have been rendered incompetent for its conducting work by the influence of the strain

There is one condition in the arrangement of a lightning conductor which is even more important than the conducting capacity of the rope or rod, namely, the freedom of its electrical communication with the earth In the case of a rain pipe, it would be of no practical utility to put up a pipe of four inches diameter, if the hole below for the escape of the water were contracted to an aperture of a quarter of an inch Yet the arrangements that are very commonly made, in what is termed protecting a house from lightning, are even infinitely worse than this It is quite a common occurrence to find lightning conductors, with ten thousand times less outflow for the electrical force beneath, than there is passage for it through the main channel of the rod The result in such cases is that the entire conductor is reduced in vertical effectiveness to the proportions of its weakest or smallest part, that is, it is made inefficacious entirely for the work that it is expected to do This practical evil is also increased in an enormous degree from the unfortunate fact that lightning conductors tend continually to get less and less efficacious in their earth-contacts from natural causes The metallic surfaces below the ground become covered over with thick crusts of oxidation, and are eaten away from combined chemical and electrolytic agency, and as this occurs, they afford no visible or palpable indication of the growing defect until grave mischief happens from some chance lightning stroke Faulty earth-contacts are unquestionably the most frequent cause of failure of lightning rods to perform the office for which they are designed

MM Pouillet and Ed Becquerel have entered upon some very laborious and exact experiments to determine the relative capacities of pure water and metallic copper to conduct an electrical current or discharge,

and they have arrived at the conclusion that metallic copper conducts 6,754 million times more readily than pure water In accordance with this deduction, a copper rod, if it were made for electrical purposes to terminate in an earth-contact of pure water, would need to have a surface exposed to the water 6,754 million times larger than the sectional area of the rod This theoretical conclusion is, however, materially affected by the fact that it is not pure water that is encountered in the pores of the moist ground It is water that contains various saline principles and other matters in solution, and these dissolved matters increase its power of electrical transmission enormously From this cause, and from some other correlative influences, it has been found that if 1,200 square yards of actual contact with moist earth is provided for a copper rope or rod eight-tenths of an inch across, that proves to be an ample allowance for all purposes But even that, it will be observed is somewhat of a formidable task It means an actual surface of contact 34 yards across in both directions The most ready and immediate means by which this large earth-contact can be made in towns is by effecting an intimate metallic connection between the lightning rope and the metallic pipes of the water supply Where this cannot be done, other expedients have to be adopted The French electricians have recently contrived a stout harrow of galvanised iron with down hanging teeth for the accomplishment of their earth-contacts, and they pack this harrow away into some moist part of the ground, surrounding it carefully with a mass of broken coke M Calland, a French Electrical Engineer of some distinction, has a refinement even upon this He anchors his rope in an underground basket of netted wire by means of a kind of coarse iron grapnel, with four up-turned and four down-turned teeth, and he packs round the grapnel within the wire basket with broken coke The coke is a very admirable agent for establishing the electrical communication between the earth and the rope or rod on account of its great porosity It is immediately saturated with moisture, when it is placed in moist earth M Calland has ascertained that two bushels and eight-tenths of porous coke afford the 1,200 square yards of contact-surface that are required The alternative, when neither the harrow nor the grapnel are employed, is to make a five-inch bore down 20 feet into the moist earth, to insert into this bore the lower end of the conductor, whether rod or rope, and then to ram it well round with

broken coke until the bore is filled. Horizontal trenches opened out in the actually moist ground, and with the end of the conductor distributed into them, with a surrounding packing of coke, answer very much the same purpose. Messrs. Gray and Son, of Limehouse, employ for their earth-contacts two divergent trenches of this character, each about 16 feet long.

My friend, Dr. Williams, who is a keen observer of most matters that concern atmospheric meteorology, tells me that in the neighbourhood of Gais, near to St. Gall and Appenzel, the beginning of the Highlands immediately to the south-west of Lake Constance, there are from two to eight lightning conductors to every house, and there are, nevertheless, conflagrations from the discharge of lightning upon the houses every season. The lightning conductors are obviously inefficient for the work which they are intended to perform, and Dr. Williams ascribes this to the insufficiency of the earth-contacts. The soil consists principally of porous limestones and conglomerates, which dry very rapidly, and in all probability the lightning rods are just placed in contact with the dry rock, without any attempt to compensate the dryness by special contrivances for enlarging the surface of communication. The rods are consequently very much in the condition of the well-known case of the Lighthouse at Genoa, in which the lightning conductor was terminated below in a stone rain-water cistern especially constructed to keep out the infiltration of the sea, or of my own instance of the lightning rod of a church tower which was packed away at the bottom in the inside of a glass bottle.

Perhaps the most important advance that has been made by electrical science in recent days in regard to the establishment of efficient earth-contacts for lightning rods, is the assertion of the principle that the efficiency of the earth-contacts must be in all cases tested by actual experimental proof. The circumstances upon which the free transmission of the electrical force depend are so complex and varied, that it is only when a direct investigation of the freedom of the transmission has been made in any individual case that all the requirements of exact science can be held to have been efficiently fulfilled, and it fortunately happens that there is an instrument in the hands of scientific men, which enables this crucial test of efficiency to be very readily applied. This instrument is the galvanometer. The needle of a galvanometer is deflected by an electrical current passing through the coil of the wire to an extent which indicates the readiness with which the current is transmitted through

the coil. Now, if both terminals of the wire of a galvanometer are placed in direct communication with each other, through short circuit, with a Leclanché Battery of a couple of cells coupled up into the circuit, and the degree of the deflection of the magnetic needle under this circumstance of free and entirely open transmission, be noted, this at once becomes a standard with which any less free transmission of the current can be compared. If, then, all other circumstances being the same, the short circuit is broken, and one terminal of the wire of the galvanometer is placed in communication with a gas pipe unquestionably in unimpeded communication with the earth, and the other terminal is placed in electrical communication with the rope or rod of a lightning conductor, the circuit in such case has to be completed through the earth-contact of the conductor, instead of through the shorter route, and if there is any increase of resistance or impediment there, this at once becomes manifest in the deflection of the needle of the galvanometer being to that extent less than it was in the previous arrangement with that circuit. If the earth-contact of the lightning rod is sufficiently open and perfect, the deflection of the galvanometer is very nearly the same in both instances. In the arrangements carried out within the last two years for the protection of St. Paul's by Mr. Faulkner, every large mass of metal in the construction of the building was brought in succession into metallic connection with the main track of the lightning conductor, and was never left, in any instance, until the indications of the galvanometer manifested that the earth-contact from it was virtually open and free, at least to within one or two degrees of the deflection of the needle. The copper ropes terminate with carefully rivetted attachments in copper plates, which are pegged into the moist earth of the sewers beneath the streets surrounding the Cathedral.

Mr. Spiller has drawn attention to the very common occurrence of the rapid destruction of a copper lightning conductor attached to a chimney-stack through the influence of the sulphurous vapours emitted from the burning coal, and has suggested that nickel plating may afford an efficient remedy to the evil, as he finds there is not the slightest action upon a nickel-plated surface after it has been buried for weeks in powdered sulphur. It unfortunately happens, however, that the conducting power of nickel is very low in comparison with that of copper, lower even than that of platinum. If silver be taken as the standard of conductibility, and be estimated as 100, then the relative value of the conducting power

of copper platinum and nickel is—copper, 91·4, platinum, 8·1, and nickel, 7·7. The relative resistance of the same metals to the transmission of the electric force, if silver be taken as a standard at 100, are respectively:—copper, 109·8, platinum, 1243·4, nickel, 1428. Protection from such fumes would probably be quite efficiently provided if the copper conductor were carefully enclosed within a leaden tube soldered over the conductor at its extremities, wherever damage from this cause has to be apprehended. This plan is adopted by the French electricians very satisfactorily in establishing earth-contacts, wherever there are ammoniacal vapours present in the ground. Messrs. Sanderson and Proctor state that they are introducing ebonite tubes for the same purpose.

Whenever different lengths of a lightning conductor have to be joined, this requires to be done with the utmost nicety and care. If there is any break in the metallic continuity, it materially increases the resistance, and impairs the efficiency of the conductor. In the case of metallic ropes, the wires are generally untwisted and spliced together where the contact has to be made, and the joint is afterwards dipped into melted solder. Mr. Faulkner effects the union of his broad copper straps by covering the joint with an overlapping plate, and screwing the whole firmly together by screws passed through the thickness of the overlapping parts. M. Francisque Michel, in renovating and perfecting the attachment of many of the unpaired lightning conductors furnished to the public monuments in Paris, has adopted the ingenious expedient of screwing on washers of soft lead very firmly between the contiguous surfaces of the interrupted joints, and then covering the whole joint up with a coating of melted solder.

The instructions of the French Académie des Sciences, issued by Pouillet in 1854, directed that the lightning conductor should be terminated above by a solid rod, if of iron, two inches and a quarter in diameter, carried up from 15 to 30 feet above the highest point of the building to be protected. The reason for this increase in the dimension of the rod at its upper extremity is found in the well-known fact that the largest disruptive effort is exerted, when an electrical discharge occurs through a line of conducting metal, at the two opposite extremities of the conductor. On this account, both the earth-contact and the upper termination must be strengthened to meet this strain. When points are employed at the upper termination of a lightning conductor, however, the need for this

increased size is, to a considerable extent, obviated, in consequence of the point setting up a continuous stream of low tension. The real value of the point indeed is due to this peculiarity. A well arranged lightning conductor, furnished with efficient terminal points, discharges or saturates a thunder cloud at a great distance silently, and almost certainly prevents any actual disruptive discharge, or flash, of the lightning. The immediate consequence of this is, that the electrical discharge passing through the conductor never reaches the condition of high tension. It flows off in a gentle stream, which never at any time has expansive energy enough to burst out from the channel provided for its conveyance, or to produce, by induction, return shocks, or other sudden and violent effects of an inductive character. The blunt conductor, struck by a true flash of lightning, on the other hand, although it may convey the discharge to the ground, is at the instant of the passage, filled with force of such high tension, and of such energetic expansion that it is ready to leap forth from the conductor to any body conveniently near, upon the slightest excuse or provocation. A living person may embrace a lightning rod discharging a thunder cloud through a point without knowing anything about the matter, but he could not do the same thing with a blunt lightning conductor discharging a thunder cloud without incurring the greatest personal danger. There are various simple experiments by which this particular power of the point may be familiarly illustrated, but a very remarkable and telling instance of this power has just been communicated to me by Mr. F. G. Smith, in allusion to some remarks I had printed on the subject. Mr. Smith was engaged in the August of 1865 in ascending the Linguard Mountain from Pontrisina in the Engadine, with three companions, and was caught during the ascent in bad weather. He nevertheless reached the summit, which is a sharp, narrow ridge, shaped like the back of a horse, and 11,000 feet above the sea. At one end of the ridge there is a flag-staff tipped with an iron point, and at the opposite end an observation disc of the same height, covered with an iron hood. When he stood upon this ridge there was nothing visible round but grey mist and falling snow, and almost immediately the otherwise death-like stillness of the gloomy spot was broken by a strange intermitting noise, resembling the rattling of hailstones against the panes of a window. A careful investigation of the cause of this noise soon made it apparent that it proceeded from the flag-staff, and that it was sometimes

at the base, then quivering all through from top to bottom, now loud, now soft, but never ceasing for a moment The rattling was in reality due to the passage of a continuous stream of electrical discharge from the cloud, in which the summit of the mountain was wrapped down the flag-staff After a little time the entire party held up the pointed ends of their alpen-stocks into the air, and immediately the same rattling noise appeared in each, and the electrical discharge was felt by each individual passing through them, and causing a throbbing in the temples and a tingling in the finger ends The noise was still going on vigorously when Mr Smith left the summit after a sojourn upon it of three-quarters of an hour The broad iron hood and flat observation plate in the meantime were perfectly untouched by the discharge

Some distinguished electricians of a past age maintained that it was of no importance whatever to place a sharp point upon the top of a lightning rod, because even a metallic ball some inches across is virtually a point to a thunder cloud on account of its being so very much smaller than the cloud This, however, is certainly a mistake Mons Gavarret, Professor of Natural Philosophy to the Faculty of Medicine at Paris, in some very beautiful experiments, has shown that the tension or striking force, which can be produced in the prime conductor of an electrical machine, is progressively diminished as longer and sharper points are brought into operation in the neighbourhood, to draw off the charge The points are placed a little distance away from the conductor, and are attached to an earth wire If a slender and sharp point exerts more exhausting influences over the charged conductor than a coarse and blunt one, it is perfectly clear that a point must exert a stronger influence over a charged cloud than an unsharpened rod or a ball

Platinum has been very generally recommended for the construction of the points of lightning rods, on account of its property of remaining sharp and uncorroded when left freely exposed to the moist air, and even when frequently transmitting streams of electrical discharge Platinum is one of the most difficult metals to melt, and is comparatively indifferent to the chemical attractions of oxygen But, on the other hand, it is unfortunately not a good conductor of electricity. It has 12 times less conducting power than silver, and 11 times less conducting power than copper The employment of platinum as the upper terminal of a lightning conductor consequently increases the resistance of the rod, on

the ground of constituent materials, at the same time that it reduces the resistance by figure when in the pointed form. Mons Fancisque Michel, the Superintendent of the Electrical Department of the Public Works at Paris, has consequently superseded platinum by an alloy of copper and silver, which contains 165 parts of copper to 835 parts of silver This form of point keeps its sharpness very well, and conducts quite as freely as the copper conductor The points are about two inches long, and are shaped off to a cone, having an angle of from seven to ten degrees They are so contrived that they can be screwed firmly home into a socket provided for them at the end of the copper rod Plain copper points, however, answer all purposes very well if they are examined from time to time, and kept fairly sharp and clean, and especially when several points are used in the place of one pointed terminal The multiple point is gradually making its way, as it thoroughly deserves to do, into general use, and into the confidence of scientific men Various forms of it have been devised, but all that is really practically needed is, that the conductor shall be branched out above, and forked out in all directions, so that there shall be points everywhere projecting beyond the cone of protection recognised by the electrician, which, to make the protection entirely reliable, should have a perpendicular height at the apex of something like half the breadth of the building Wherever the building extends beyond, or even approaches near to the limits of this conical surface, there should be a point pushed out a little further still, and at the same time connected metallically with the general stem of the conductor M Melsens, the Belgian electrician, who has recently perfected the protection of the Hotel de Ville in Brussels, has left that large building literally bristling over with points There are as many as 228 copper points and 36 iron points comprised within this system of defence, and it is quite impossible to conceive any more effectual arrangement of the upper terminals of a lightning conductor

M Melsens in his practice adopts the generally accepted plan of connecting all large metallic masses contained within the building with the main stretch of the conductor, but he does this after a fashion somewhat peculiar to himself He makes the connection by means of closed circuits, that is, he attaches the metallic mass to the lightning rod by two distinct metallic strands, carried to two distinct points of the rod He considers that in this way the protection against inductive disturbance

and return shocks is more absolute and complete, and he, no doubt, has in support of his view the authority of Professor Zenger, of Prague, who has devised some experiments, which he conceives to demonstrate that the best of all protectors is a circular segment of metal carried transversely overhead across the area containing structures that have to be defended M Francisque Michel, and most of our own electrical Engineers, in the meantime, adhere to the practice of connecting all large masses of metal in a building with the lightning conductor by a single metallic strand

M Calland, a French electrician, who has recently printed an interesting book on the lightning conductor, objects strongly to this practice of connecting masses of metal entering into the construction of the building with the lightning rod, and also insists upon the insulation of the rod itself from the masonry of the building by non-conducting supports, such as are used with telegraph wires—an expedient that has been for some time almost universally abandoned, so far as the lightning rod is concerned M Calland's reason for this course is perfectly intelligible He contends that metallic masses employed in the ordinary work of construction are frequently placed where living people have occasional access to them, as in the instance of an iron balcony projecting in front of a French window, and that where this is the case, the danger of such people is materially increased if the metal work or balcony is connected with the conductor, because then the living body is apt to form a stepping-stone of approach, if the lightning passes that way to the system of the conductor M Calland argues, and so far argues correctly, that the lightning rod is very much more likely to be struck than the masonry or woodwork of a building, and that any metallic appendage, such as an iron balcony, stands in the category of the conductor when it is connected with it, and in that of the masonry when it is not so connected Thus a living person placed near to a balcony, that is connected with the rod, is, in the same degree, more likely to be struck by a discharge than a person placed near a balcony that is without such metallic connection The practical inference is, that metallic masses in a building should always be metallically coupled up with the lightning conductor when they are so situated that they are not liable to have living persons near to them during the prevalence of a storm, and that they should be left unattached to the conductor when they are so situated as to be of ready

access to persons inhabiting the buildings It should, however, be also clearly understood that this connection or non-connection of incidental masses of metal is of no practical moment whatever when a building comprising them has a really efficient lightning conductor, with ample earth-contacts, and an abundant supply of well arranged points dominating its entire mass It is only when a conductor is in so imperfect a state, or is so badly planned, that subordinate masses of metal can act as recipients, and feeders of the discharge through the earth contacts, that the question of connection of such masses with the conductor becomes one of practical moment A properly planned lightning conductor should cover and afford absolute protection to all that a house comprises and contains, and should render a lightning stroke to any subordinate part of the structure a virtual impossibilty M Calland seems to insist upon the support of the lightning rod by insulating attachments, principally because it is a part of his general principle of avoiding electrical connection with the structures of the building My own impression upon this point, however, is that it is certainly a work of superfluity to take any trouble about such insulation In a considerable experience with lightning conductors, in which insulation has never been adopted, I have never known any case of injury, even of most trifling kind, from this cause Messrs Gray and Son have met with one curious and notable case, in which a copper rope, which had been grasped by insulating conductors, had been broken and disintegrated wherever the rope had been connected with an insulator This result, however, was most probably due to some mechanical cause, affecting the molecular condition of the strained wires at those points

The insulation of the rod certainly promotes, rather than prevents, the production of the incidental sympathetic discharges, which are known as "return shocks" These "return shocks" are entirely due to the operation of induction When a lightning rod is placed in a state of high electrical tension in consequence of being under the influence of a neighbouring storm cloud, it immediately calls up inductively a similar state of electrical disturbance and tension in material masses that are near to it, but separated from it by a non-conducting space or gap When the storm cloud is suddenly discharged under such circumstances, whether through the conductor, or by some other route, the tension in the conductor is instantaneously relieved, and at the same moment all secondary tensions produced by it are also terminated in the same instantaneous

fashion The secondary tensions, under these circumstances, are very apt to leap to the earth through more or less imperfectly conducting routes of their own improvising, and to produce some mechanical disruption in doing so The proper and effective cure for such incidental disturbances is the employment of such a system of pointed terminals as renders the production of any state of high electrical tension in the conductor impracticable

The "tall-boys," or metallic chimney-pots, so commonly employed in towns to increase the force of the chimney draughts, may be eminent causes of danger in houses not furnished with lightning rods, because the column of heated air ascending to them from a burning fire through the chimney is a conducting route of considerably diminished resistance as far as the fire grate, but it is a conducting route that generally terminates there, and that, therefore, is very apt to lead a lightning discharge to the earth through the intermediate steps of living persons inhabiting the room The "tall-boy," on the other hand forms a very ready base for the support of an efficient point, if it has the conducting route from it to the earth completed by a competent rod earth-contact Messrs Gray and Son, of Limehouse, speak of one case in which a large and lofty chimney-shaft of brickwork was materially damaged by a lightning stroke, although the chimney had an apparently good lightning rod fixed at one side of the shaft The point of the chimney at which the electric discharge came into communication with the ascending column of heated air was, in this instance, four feet and a half nearer to the discharging cloud than to the lightning rod The discharge in this case found the column of heated air, the surrounding brickwork, and the furnace beneath, which was some distance away from the bottom of the chimney-shaft, an easier path of escape than the lightning rod The Messrs Gray advocate the surrounding of the top of tall chimneys with a complete edging of copper bands to obviate the possibility of accidents of this character

A well-arranged multiple point reared well above the chimney, and protected from the corrosive action of sulphurous fumes, would, no doubt, answer quite as well In the case of large and costly structures both plans may, nevertheless, be advantageously combined

Rain-water pipes, which are indispensable contrivances in all houses, may be easily turned to account as lightning conductors, but they must then be made metallically continuous from some prominent point or points above to an efficient earth-contact All joints in the pipe must be absolutely

neutralised by well attached strips of metal carried over them from length to length, and over and above this, care must be taken that they are not within striking distance of any superior line of conduction at lower parts of the house, as, for instance, gas pipes connected with the main service If they are within such striking distance, there will always be a probability that a discharge may leap across from them to the secondary line of conduction, and do mischief of some kind by the way The Messrs Gray have had one case within their experience, in which a discharge of lightning leapt in this way from a rain water pipe to an iron gas pipe, and made a breach of continuity in the latter, and set light to the gas.

It is very much to be desired that protection from lightning should enter as essentially into the designs of architects who plan houses as protection from rain Sir William Snow Harris holds the honorable position of having established that doctrine in regard to ships, and of having perfected a plan for their protection from lightning that leaves scarcely anything to be desired Damage from lightning to vessels of the Royal Navy is now virtually an occurrence that is never heard of The day, in all probability, will come when the same remark will be able to be made in reference to houses, at least where these are gathered closely together into towns It is, indeed, quite possible that towns may be made to bristle with pointed lightning conductors, until no charged thunder cloud could retain a high tension charge when within striking distance, so that the flash of disruptive lightning would be virtually banished from the urban precincts This is really what has pretty well happened in the case of the Capital of Colony of Natal, where lightning rods of good construction have been rapidly multiplying in recent years. Damage from lightning is now scarcely ever heard of within the town, although the lightning is seen flashing immediately around with the most vivid intensity every second or third day through the six months of the hot and wet season

Until lightning conductors are supplied with the rain water pipes to houses as part of the architect's design, all intelligent men should know just enough of leading principles of electrical science to be able to make such arrangements for themselves, for the efficient protection of their houses from lightning, as have been briefly glanced at in this paper. The indispensable conditions that have to be secured in accomplishing this are simply :—

1. The lightning conductor must be made of good conducting material metallically continuous from summit to base, and of a dimension that is sufficient for the ready and free conveyance of the largest discharge that can possibly have to pass through it 2 It must have ample earth-contacts, and these contacts must be examined frequently to prove that they are not getting gradually impaired through the operation of chemical and electrical erosion 3 It must terminate above in well formed and well arranged points, which are fixed and distributed with some definite regard to the size, form, and plan of the building 4 There must be no part of the building, whether it be of metal or of less readily conducting material, which comes near to the limiting surface of a conical space, having the highest point of the conductor for its apex, and having a base twice as wide as the lightning conductor is high, without having a point projected out some little distance beyond, and made part of the general conducting line of the lightning rod by a communication with it beneath 5 There must be no mass of conducting metal, and above all things, no gas pipe connected with the main, within striking distance of the lightning rod, lest at any time either the points or the earth-contacts shall have been so far deranged or impaired as to leave it possible for discharges of high tension, instead of continuous streams of low tension, to pass through the rod, and to be diverted from it into such undesigned routes of escape

Discussion

Mr Pastorelli, in alluding to the importance of the paper, remarked that he believed the public were very ill informed on the subject of lightning and conductors With respect to the forest of metal chimney-pots in towns, they enjoy comparative immunity, this he attributed to the proximity of church steeples and other high buildings provided with lightning conductors, for at their points the electric fluid would have a great tension, and tend to flow towards the storm cloud, forming, as it were, a channel for the passage of the electric fluid from the cloud to their points If zinc pots were placed on an isolated house in a large open space, they should be connected with a lightning conductor, otherwise they would prove most dangerous.

Mr. Strachan said it appeared to him that the rules for constructing lightning conductors were framed very much upon guess work, and he supposed this must be so, but there was a tendency to idealise too much.

The practice of the Engineers who did this kind of work was not uniform, much of it depended upon individual opinion, often crotchety, and seldom admitting any proof of efficacy Was it demonstrated that the resistance of the conductor increased with its length? Was there any certainty of the utility of a couronne of points? Beyond the simple facts that the conductor should be pointed, continuous, and led into moist earth or water, very little seemed known for certain as to the best construction of lightning rods There was a tendency to make them complicated, notwithstanding that the lightning rod in its simplest form as hitherto used had been evidently useful, especially for ships It is very seldom now a day that ships were struck by lightning, and we infer that this is because their masts are iron or fitted with conductors The last instance known to him was that of Her Majesty's Ship *Shannon* in or about 1857, which lost topmast, although it was fitted with Harris' conductor, but suffered no other injury, from a terrific lightning flash

Mr T G Smith, in reply to the Chairman, who asked whether he could add anything to the brief account that had been given by Dr Mann of his notable experiences on the Linguard, said that the occurrence which had been alluded to was certainly a startling incident He did not think he was altogether a coward, but certainly the first impression made upon him when he realised the position his party was one of some alarm. There was, however, no ready means of escape from the position They were wrapped round with the electrically charged cloud, and as the discharge continued so gently, familiarity with the situation soon bred a sort of contempt They first stretched their alpen-stocks out to experiment with the wooden staffs upwards, and they then distinctly felt the electrical thrill passing through their bodies, and heard the crepitating currents rustling into the staves, thereupon they turned the iron points upwards and the crackling sound was immediately increased, and the thrilling sensations became much more powerful, they then experienced the sensation very strongly both in the temples and at the fingers-ends The direction plate was of brass, and marked with lines to indicate the points of the compass and the direction of certain prominent objects in the surrounding country, and was mounted upon stone, it was covered by a large iron hood some two feet or so across, there was no electrical discharge of any kind upon it. He had no doubt whatever that the points of the flag-staff and of the alpen-stocks had really served as efficient safeguards to

his party, lessening the tension of the electrical charge which was immediately around them there must have been an enormous discharge during the time they remained upon the summit, for it was continued unceasingly for three-quarters of an hour

Mr D Pidgeon said he spent last winter with his family in a house built upon the cliffs which form the promontory of Rounham Head, in the Parish of Paignton, about three miles from Torquay It is a bold head occupying a central position in Torbay, and juts well out to sea, the house occupying a very exposed position, with the sea a near neighbour on three of its sides From the grounds, a door upon the cliff gives private access to the shore by means of steps roughly hewn out of the sandstone rock, and these formed a favourite position for watching the beauties of the bay both in calm and stormy weather Hard by the door stood a flag-staff originally put up for the use of the coast guard, but now forming part of the property It consisted of a single mast, 50 feet high, very strongly made, and substantially erected, having a metal vane at the top, and stayed about 25 feet from the ground in the usual way, with galvanized iron wire guy ropes About a foot above ground the wire ropes terminate in half-inch cable chains, which are carried some way into ground to an anchorage These chains are much corroded, the metal in some of the links being reduced to about one-eighth of an inch diameter, while others remain of about their original size The soil in which the chains find an anchorage is red sandstone conglomerate, which from its position is perfectly drained and very dry

February 25th was a day of incessant rain from early morning till mid-day, with a cold wind blowing strongly from south-east Soon after noon the clouds broke, and the afternoon was made very beautiful by a series of brilliant and changing atmospheric effects Wind-galls were frequent, and the sky now bright, but streaked with "mare's tails," now dark with a passing scud At no time during the day had there been any sign of thunder About 5 P M, tempted by the beauty of the bay, his wife, his son, and himself were on the shore, when a scud came up with the wind and approached them rapidly, they watched its course over the bay from Berry Head, and when it neared, fearing a wetting, they made their way homewards by the rock stairs The first drops of the shower fell as they reached the flag-staff, and proving to be hail, they halted, standing in partial shelter grouped around the staff, while waiting

for the scud to pass. His wife and son occupied the doorway, the former looking over the door out seaward, the latter close to her, and both a distance of 10 feet from one of the mooring chains. He stood some 20 feet from them, and 10 feet from another mooring chain. While in this position, a flash of lightning struck the flag-staff, breaking the mast short off immediately below the metal vane as well as at a point 11 feet lower, rending into shivers all the wood between the vane and the point of attachment of the wire guys, and scattering the splinters in every direction, while the wreck of vane and mast fell within a few feet of their party.

On examination it was found that the broken staff was blackened round half its diameter, the edges of this discoloration forming ragged splashes; the brass tube of the vane was ripped open for four inches along the joint at top and bottom, and all solder about the vane was melted. Three of the mooring chains were broken, the links being snapped short across in many places, and some of the links fractured in more than one place. The broken surfaces were bright and crystalline, showed no signs of heat, and no diminution of sectional area at the points of fracture. About 20 links altogether were broken, some above and some below ground, many of those which had suffered most from rust were snapped, not across the reduced, but across the full section iron. It is worth noting that one of the rusty chains had given way in a gale some time before this occurrence, and that his son had mended it temporarily with an S hook made of galvanized wire not more than one-tenth of an inch diameter. In this chain several links were broken through their full uncorroded diameters, while the slight wire S hook remained intact. Fragments of the shivered wood were found 150 feet to windward, measured distance, those flying to leeward would fall into the sea. The flag-staff formed the centre of a wide circle of gravelled path, from which other gravelled paths led to various parts of the garden. At the point where each mooring chain entered the gravel, a notable pit-like depression was formed, and a walking stick could be easily thrust into the ground for nearly a foot in each pit. On one of the paths radiating from the staff, and about 20 feet distant from it, stood an iron garden roller. A shallow trench in the gravel forking into two sinuous scores radiated from the mast towards this roller. The shorter of these, eight feet long by four inches wide and three-quarters of an inch deep, terminated in a splash

of gravel on the periphery of the roller at its point of contact with the ground The longer score left the roller on one side, and was lost in the gravel some four feet beyond it Two other similar but small scores were traced about an iron drain grating in the same path, and a score six feet long ran along the gravel path to the spot where he stood All these scores or trenches were roughly radial to the staff

Very heavy hail followed the flash, and the sky became exceedingly threatening, the wind fell instantly on the discharge to a dead calm Twenty minutes later a second but distant flash was seen, after which there was no more lightning

To observers placed anywhere within three miles of the spot, the lightning appeared as of very exceptional intensity The coast Guard Officer, distant some quarter of a mile, compares the explosion to that of a 300-pounder gun His servants in the house, distant 150 yards, "never saw such a flash," and a scientific friend at Torquay described both flash and crash as "terrific"

In describing the effects upon themselves, he felt so strongly the danger of including subjective matter, that he would confine himself strictly to repeating the statements which they made to one another respecting their sensations immediately after the occurrence, and before their minds had time either to forget or add, in any degree, by reflection to the facts

Of the three, his wife alone was felled to the ground, his son and himself remaining erect, and all three retaining consciousness When the flash occurred, his wife was looking seaward over the door as mentioned above, but they found her lying on her back upon the ground in precisely the opposite direction, her face being turned away from the bay None of them have any certainty of seeing a flash, and his wife is quite sure she saw nothing Similarly, none of them heard the terrific explosion accompanying the discharge, but his wife was conscious of a "squish," recalling squibs to her mind, his son of a loud "bellow," while he seemed conscious of a sharp "spang," with little hold on its objective reality His wife describes her general sensation as that of "dying away gently into darkness," with a distinctly subsequent feeling of being roused by a tremendous blow on the body On raising her from the ground she complained of great pain in the legs, which refused to carry her, and they had to support her into the house The lower limbs remained paralysed for some time, giving at the same time great and alarming pain, but this passed

off in less than an hour On undressing her, a distinct smell of singeing was noticed, and she was covered from the feet to the knees with tree-like marks branching upwards of a rose red colour, while another large tree-like mark, having six principal branches radiating from a common centre, and 13 inches in its largest diameter, covered the body It is worthy of remark that the centre of this figure coincided exactly in height from the ground with the iron bolt of the door against which his wife was leaning, and it also marks the spot where she was conscious of having received a violent blow

His son affirms that he received a violent shock in both legs, and that it was electrical in character, while he was conscious only of a sudden and terrific general disturbance affecting chiefly his left arm and throat, but with nothing electrical about it It is certain that some appreciable time elapsed before any of them referred the occurrence to its true cause His wife remained under the impression that they had been fired upon, and that she was wounded, until he told her that the mast had been struck by lightning His son and himself had both a momentary feeling of intense anger against some "persons unknown" for what they thought was a trick He did not think he recognised lightning till after his first glimpse of the wreck lying on the ground around them His wife is the only one of the three who had any sensation of smell, and she is quite clear on the point The lighting of a match was sufficient to bring the occurrence back vividly to her mind for a long time afterwards For a very few moments, both his son and himself failed to articulate, their mouths moved in an attempt to speak, but the first few words on both sides were quite unintelligible That there was an unconsciousness to surrounding objects of some seconds' duration is clearly shown by the fact that none of them saw or heard the heavy mast fall to the ground, though, descending through 50 feet, it must have taken at least two seconds to reach the earth A correct drawing of the chief lightning impression on the skin described above, was carefully made from measurements taken at the time The branches were about a quarter of an inch in width, bright rose red, and were all faded away in four to five days. The skin, where reddened, was sore to the touch like a scald or burn

Dr Tripe said he did not propose discussing Dr Mann's paper, but desired to make some remarks about ball lightning On the 11th of July of last year he was watching the progress of the most fearful storm he

ever witnessed, of hail, rain, wind, and lightning, and was looking due south, where he saw a large ball of fire rise apparently about a mile distant from behind some low houses This house is situated on the borders of the London fields, which are, in that part, about a third of a mile across, so that he had an uninterrupted view of the phenomena The ball, which appeared about the size of a large cricket ball, at first rose slowly, but accelerated its pace as it ascended, so as gradually to acquire a very rapid motion When it had risen about 45° it started off at an acute angle towards the west, with such great rapidity as to produce the appearance of a flash of forked lightning It made three zig-zags before it entered the dark cloud, from which flashes of sheet lightning were coming About 10 minutes afterwards he saw a similar ball, which, however, rose more to the west, in the direction which the electrical cloud was taking, when a similar occurrence took place, the ball rising to about the same elevation before starting off as a flash of forked lightning These balls seem to be dissimilar to those which descend, as the pace is greater at the latter part of its course, and the colour lighter The colour of the ascending ball lightning which he had seen was light yellow, whilst that of the descending ball was bluish

Dr C J B Williams remarked, in reference to Mr Pidgeon's description of his stroke by lightning, that he neither saw the flash nor heard the sound, that such was the common experience of those struck by lightning, they were so stunned by the shock to the nervous system, that all sensation was suspended for the moment when they recovered consciousness they could not speak for a time, because the muscles concerned in speech were benumbed from the same cause With respect to the ball of fire, moving deliberately, and then passing into a flash of lightning, he must doubt the identity of the phenomena After such evidence, he would not question the reality of the ball of fire as an electric meteor, but its slow motion and course must distinguish it from the lightning flash, which darts from east to west, from one horizon to its opposite in an inappreciable instant of time To find its analogue in experimental electricity, we must seek for the representation of the ball of fire in the brush or star, or some such slow coruscation of electric light, and not in the vivid and instantaneous spark from the battery discharge, which truly represents lightning To turn to a more practical part of the subject, he wished to call attention to the remarkable liability of some districts to thunderstorms, and their

great need of efficient protection Two years ago he visited Gais, a high village of Appenzel in Switzerland, famous as a resort for the milk cure He was surprised to see that every house had its lightning rods, in number varying from two to eight, according to the size and complexity of the building On inquiry, he found that the place was subject to the visitation of thunder-storms so terrific and frequent, as to keep the inhabitants in continual dread, and in spite of the protection of the conductors, conflagrations were very common A storm, which raged for 10 hours, had occurred in the previous week telegraph posts were shattered to splinters, and two châlets were burned to the ground, although each of them had two rods He had met with nothing like it in other parts of Switzerland, however high and exposed He thought this extraordinary proclivity to thunder-storms must be due to the fact that this district forms the first high land after the wide expanse of the Lake Constance, and the vast plains of Wurtemberg and Bavaria, which are comparatively low Although rising little more than 3,000 feet in height, it formed the foremost spur of the Sentis Range, and would attract the clouds charged with negative electricity, which gathered from the plains below Such was a place to test the efficiency of the protecting rods, and nothing was more likely to cause failure than want of moist conduction to the earth under the houses with projecting roofs, and where the underlying rock is dry limestone and conglomerate

A preceding speaker had alluded to the danger in towns from the many zinc and iron chimney-tops without sufficient conducting connection with the earth, but he believed this danger to be confined chiefly to isolated buildings, or scattered villages, where the chimney-cans are few In large towns there is such a forest of metallic tubes, more or less angular or pointed, that even with imperfect conducting power, they must draw off quietly a great deal of electricity, and render towns more safe than country He would apply the same remark to large trees, which, although not perfect conductors, are moist enough to draw off a vast deal of electricity from the clouds In his youth he resided opposite some of the highest trees of a large park, and he had often noticed during a thunder-storm a little column of smoke above some of the topmost boughs After a few months these boughs were dead, doubtless gradually killed by the heating effect of the electricity in passing through their imperfectly conducting material Often since, in Hyde Park and elsewhere, he had noticed that

the topmost boughs of the highest trees were dead, he believed from the same cause Although heated and injured by its transit (like a fine platinum wire by a battery) trees gave proof that they do draw off electricity from the clouds, especially when wet, and thus diminish the danger to the adjoining country

Mr Scott said that there could be no doubt as to the occasional occurrence of globular lightning, which moved very slowly, the evidence of this was too strong to be controverted With reference to the possibility mentioned by Dr Williams of the tops of trees being killed by constant electric discharges passing through them, he would like to ask whether this was not more commonly attributable to the fact of excessive drainage, as in Kensington Gardens, having affected the health of the tree He finally drew attention to the constant error of stating that the lightning rod drew the electricity out of the cloud, whereas it more correctly might be said to allow the electricity to escape from the earth

Mr Burt said that on the occasion of the storm alluded to by Dr Tripe two elms situated near Leyton Green, about a quarter of a mile from his residence, were struck by lightning The upper branches of one were completely withered, but otherwise the tree was uninjured The path of the lightning is not only traceable, but distinctly visible, along the trunk of the other now standing, a portion of the bark between 15 and 20 feet above the earth's surface of about six inches wide having been torn away It was at this point that the lightning appeared to have left the tree, for below it the trunk is apparently sound, the lower branchlets having produced healthy shoots this spring There were several trees in his immediate neighbourhood that have lost their upper branches, and he was disposed to regard lightning as the agent which had killed them

Mr Whipple asked if Dr Mann would state what was the electrical conductivity of bricks when wet He thought that a house covered with a metal roofing would be as safe as if bristling with points With reference to what had been said about locality, he would mention that some time ago a tree was struck by lightning in Richmond Park, and on going to see it, he found that it was on a spur of a hill stretching out from Richmond Hill. He believed that ball lightning was a reality, for a friend of his had described to him the track of a ball in his garden which went off in the same way as mentioned by Dr Tripe

Mr. Field asked whether the pipes for the ventilation of drains might

not be dangerous as attracting lightning, unless properly connected with the earth, and whether by proper connection they could not be made good lightning conductors.

Dr. Mann said, in reply to various remarks that had been made, and in allusion to some matters that had been suggested during the discussion, that these had been of so interesting a nature that he could only regret there was not larger opportunity to dwell upon them adequately, because there were so many topics to deal with. In reference to the case of the metal chimney-pots in great towns, he quite believed they might, when very numerous and closely planted, conduce to silent and gradual discharge, and that this was one reason why accidents from them were not more frequent. Large masses of bad conducting material, metal-tipped with sharpish edges in this way, would carry off as much electrical discharge as small rods of good conducting capacity, and this would more especially happen where there were soot-blackened chimneys leading quite down from them to near the earth. In reality there was no absolute distinction between conductors and non-conductors in electrical science, it was merely a case of degree. Everything conducted in some degree, but more or less, according to its nature. In regard to resistance being increased in proportion to the length of the conductor, as well as to its smallness, that was thoroughly well known to electricians, and he had already given the expression for the fact, as it had been ascertained by direct experiments, in scientific form in the paper. Mr. Cobb had correctly accounted for the accident to the *Shannon*, but he thought he might also add that the old practice in regard to ships was to care more about massive terminations than points. He still found remnants of this tradition in the practice of Mr. Gray, who was the skilful successor of Sir W. Snow Harris in this particular branch of work. Wherever unpointed terminals were used, there would always be much greater mechanical effect produced at the termination of a conductor than within its main line. This was an additional reason for the adoption of points. He could not admit that there was resistance of any kind set up by points, the operation was entirely the other way; resistance was diminished the instant a pointed form was given to the termination of a conductor. But he must add that he doubted whether Mr. Lecky really meant "resistance" when he used the word. He simply, he believed, wished to bring prominently out the fact, that when points were employed, there was a double

action set up by them—an influence in a double direction, a stream of electrical force was poured out from the earth through the point to the air or cloud, and another stream was simultaneously drawn from the cloud to the earth. In this Mr. Lecky was unquestionably right. The well-known experiment with the discharge of a Leyden jar through a card points to a double passage even more strikingly than Mr. Lecky's double trial left upon the glass from a discharge by overflow. Points of metal connected one with the inner, and the other with the outer, coating of the Leyden jar, are placed touching opposite surfaces of a card, and when the discharge is passed through the card, both surfaces are found raised outwards; there is a convex burr in both directions. This is generally accepted by electricians as indicating that the opposed forces cross each other in opposite directions whenever there is an electrical discharge. The term "ascending" and "descending lightning" can only be tolerated by exact science, if taken in the limitation of expressing the direction in which the mechanical or material effects of the discharge are propagated. M. Calland, in reference to this very question of the cross passage of the double discharge, says—"The lightning does not fall. The two electrified bodies produce between them an exchange of fluids, when the electrical tension of these fluids is sufficiently intense to conquer the resistance of the insulating substance which separates them." "Le ruban de feu qui unit le nuage à la terre va aussi de la terre au nuage." The transport of ponderable matter can only be looked upon as an indirect and secondary mechanical effect of the discharge, and can never be taken as indicating the direction of the movement of the discharge itself. Mr. Smith was assuredly within reason in his inference as to the large amount of the electrical discharge through the flag-staff and alpen-stocks on the Linguard. Arago estimated the amount discharged by a system of points placed upon a palace by Beccaria under somewhat similar conditions, as being enough to kill 3,000 men in the hour. In considering the interesting instance supplied by Mr. Smith, however, it must not be overlooked that the flat direction plate and iron hood were mounted upon stone, which is a much worse non-conductor than wood, such as formed the staffs of the flag and of the alpen-stocks. Dr. Williams' view as to the physiological influence of the Torquay discharge upon Mr. Pidgeon, and his companions, is unquestionably philosophic and correct. When Professor Tyndall accidently received the shock of the large Leyden battery of the

Royal Institution through him, he was quite unconscious of having bee struck by it, and felt absolutely nothing Mr Pidgeon's case was, in a probability, a strictly analogous one He states that he was quite unabl to say absolutely whether he felt any shock He was puzzled and con fused, and seems most inclined to think he was not struck, because h could not distinctly bear testimony to the shock His state of bric inability to feel and move, however, sufficiently manifests that some dis charge did pass through him In the case of Mrs Pidgeon, the mai of the discharge was left stamped upon the skin In Mr Pidgeon's in stance the full lightning discharge obviously did not pass through hin and his companions Either they were under the influence of a secondar return shock at the instant of the discharge of the lightning, or the dis charge passed from the chains at the bottom of the metallic stays of th flag-staff expansively and centrifugally to a very large area of the imper fectly conducting ground, affecting everything in a comparatively sligh degree through a very large space, the living bodies chancing to be place there amongst the rest In a somewhat similar case, recorded, if hi memory did not deceive him, by Mr Walker, the lightning was once see to make its escape through a dry earth-contact of a lightning rod of a hous in Philadelphia, as a broad sheet of fire several yards in extent The bal lightning is a well known and carefully observed phenomenon, and is i every case diagnosed and distinguished from ordinary lightning by it very slow progress, allowing, indeed, ample time for its movement to b leisurely observed But the "fire-balls" Mr Pidgeon speaks of wer manifestly not of this character, they were seen by persons "standin with their backs to the discharge" They were simply the glare of th instantaneous light filling for an instant the space immediately around th spot most immediately affected by the final communication with the earth

The disruption of the chains is one of the interesting incidents o Mr Pidgeon's case Mr Pidgeon states that not less than 20 links wer broken across This was due certainly to molecular disturbance mecha nically produced in the substance of the chain at the instant of the dis charge, and possibly taking effect most violently at parts of the meta which were already in a state of flaw, or approximate disruption Th power of lightning to contract materially the length of metallic masse when it passes through them has been observed in various instances Mr Walker has placed upon record one case in which a wire was so shortene

in a house in Stoke Newington by the passage of a discharge of lightning through it, that a night bolt, with which it was connected, could no longer be thrust into the fastening which previously received it. Some action of this kind possibly contributed to the fracture of the chain links at Torquay. The destruction of the vitality of the upper branches of trees by electrical action, spoken of by Dr. Williams, is a well-known effect. Mr. Viollet-le-Duc describes a space of 500 metres square, in the forest of Compiégne, in which all the upper branches of large trees have been stripped of foliage by electrical agency, although the lower branches of the same trees are untouched. The cups of an anemometer, such as are spoken of by Mr. Field, are of such small dimensions, that they could hardly be considered in themselves as causing any material increase of danger. But the correct principle, of course, is that such objects should be dominated by a lightning conductor. The stripping of the gilding from the column beneath the chain cable affected by the lightning discharge brought under notice, was most probably due to inductive influence, and to a secondary lateral discharge. It has already been suggested by Mr. Preece that pipes used to ventilate the sewers might be converted into lightning conductors. To use them for that purpose, it would only be necessary to see that they were of sufficient dimensions, and to furnish them with good terminal points, and with good earth communications.

[A larger copper tape than the one previously described, two forms of copper multiple conductors, and a plan for securing metallic conductors against the influence of corrosive fumes by tubes of ebonite, were exhibited at the close of the Meeting by Messrs. Sanderson and Proctor.]

Dr. Mann finally drew attention to various subordinate matters that, in connection with this subject, especially require more extended investigation, and he especially referred to the dimensions of conductors, the effects of the practice of coating good conducting substance with metals of inferior power, earth-contacts in general, and especially the competency of the ordinary telegraphic methods for testing maintenance of efficiency in them, the phenomena of return shocks, and of lateral and divergent strokes, the area of absolute protection, the systematised connection of metallic masses, the cause of the disruption of chain links, protection of lightning conductors from corrosive fumes, the protection of chimney shafts, the molecular change effected in copper by time, the height and distribution of the upper terminal of lightning rods, and the

best construction of points He also stated that it was under the consideration of the Council of the Society to determine whether a permanent Lightning-rod Committee for the further investigation of such matters might not be advantageously formed If such a Committee were constituted, its immediate functions would probably be threefold—1st, to collect and record facts relating to accident and injury from lightning, 2nd, to investigate certain moot points of scientific principle and construction, such as those which had been specified, and 3rd, to report and publish the progress of its labours in both directions from time to time

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Committee of the British Association for the Advancement of Science—re-appointed at the Meeting at Bradford to investigate the efficacy of lightning-conductors, to give suggestions for their improvement, and to report upon any case in which a building professedly protected by a lightning conductor has been injured by lightning—consisting of James Glaisher, *Esq, F R S, Lieutenant-Colonel* A Strange, *F R S, Professor Sir* William Thomason, *F R S,* Charles Brooke, *Esq, F R S,* Charles V Walker, *Esq, F R S,* M DeFonvielle, *of Paris, Professor* Zenger, *of Prague, and Dr* Mann, *(Secretary)*

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The Committee charged with this investigation and report, desires to have as much information as possible regarding accidents from lightning But in order that information of this class may possess scientific value, it is essential that all statements communicated should be clearly and definitely expressed, that they should be carefully authenticated, and that the address, as well as the name, of the observer should be given, to allow any further inquiry to be instituted that may be found to be desirable in the circumstances The Committee has consequently drawn up the following memorandum to define the nature of the information it seeks, and earnestly requests that any person who may chance to know of accidents from lightning, or who may be able to give practical assistance in this inquiry, in the sense and particulars suggested by the memorandum, will address such communications as they may be in a position to make on these subjects, to the Chairman of the Permanent Committee on Atmospheric Electricity and Lightning-rods, Meteorological Society, 30, Great George Street, Westminster, London

Memorandum of information required in any case of accident from lightning

1 The day, hour, and place of the occurrence

2 The exact nature of the occurrence, especially specifying any unusual appearance or sound that has attended the discharge of lightning

3 A minute and precise description of any damage that may have een produced by the discharge

4 Record of any visible traces of electrical action that may have been ft in the track of the discharge

5 The names and addresses of any persons who may have witnessed he actual discharge producing damage, or who may have suffered in any ay from its effects

6 The existence or non-existence of a lightning rod in any form in he immediate neighbourhood of the accidents, and an exact description f the rod when any such appendage has been ascertained to be near, especially as to—

(*a*) the nature of the metal of which the rod is composed

(*b*) the size of the rod

(*c*) the character of the conductor, whether it has the form of a solid cylinder, of a tube, of a flat strip, of a chain, or of a wire-rope

(*d*) the actual continuity of the conductor from end to end

(*e*) the character of the termination above, and the distance to which it extends there beyond any building or solid structure

(*f*) the character of the termination below whether in dry or moist ground, how it runs into the ground, and how the earth-contact is ultimately made

(*g*) the manner in which the conductor is connected with any building, and especially whether there are any masses of metal in the building near, and whether such masses are or are not placed in metallic communication with the conductor

7 Allusion to the fact whether the injurious discharge did or did not orm part of an ordinary thunder-storm in progress at the time

8 In case of the occurrence of a thunder-storm in progress at the ime of the discharge, a description of the character of the storm as to ntensity, duration, fall of rain, and apparent movement over the locality

9 Any subsidiary or incidental observations that may have been made, nd that may seem to bear practically upon the physical conditions and circumstances of the phenomenon

No. CCVII.

IMPROVED FORM OF THERMANTIDOTE.

[*Vide* Plate XLIX.]

BY H. BULL, ESQ., *Asst. Engineer, Military Works, Agra.*

IT is a matter of much surprise that whilst a good thermantidote is, during the hot weather, a very great want, if not an absolute necessity, one meets with so few whose action is really satisfactory. Most are so constructed, that when one puts one's neck actually in the outlet channel, a refreshing and perhaps strong breeze is felt, but a few feet off the effect seems entirely lost. The drawings accompanying this Article are of a thermantidote, the details of which having been first worked out theoretically, were found in practice to be thoroughly effective, and are sent for publication, in the hope that they may be of use, not only to the Engineering profession, but to the general public. The construction is extremely simple—the lower half of the air chamber is of brickwork, the side walls only being of necessity set in lime, the inside faces being all pucka plastered. The upper half is removable at will, being constructed of one inch planking at the sides, and the curved part of thin iron sheeting, stiffened by cross pieces, to which, and also to the sides, the sheeting is nailed or screwed. In the fans there are no complicated joints as in an ordinary thermantidote, each arm, or rather each pair of arms, is cut out of a one inch plank to the requisite shape, the three double arms are then set into the required position, the $\frac{1}{4}$-inch clamping plates set on either side in the middle, and the whole screwed up with $\frac{3}{8}$-inch bolts, care having been taken to fill in between the planks and between the planks and plates, with stiff glue, and also that the hole for receiv-

ing the spindle has been properly cut The supports of the bearings may be of stone or wood, the former in preference The only parts requiring skilled labor are the bearings and spindle, these should be truly turned, so that there may be as little friction as possible, the former being of brass The cost of the spindle and bearings should not be more than Rs 25, the remainder of the work costing about Rs 125, making a total of Rs 150

The cover is shown much wider than it need be, one inch clear play for the fans (the same as in the lower part of chamber) being ample, the side planks are one inch thick, stiffened by pieces $1\frac{1}{2}$-inches thick Blocks of wood are placed directly under the bearings, and also as a sort of washer under the stone, to act as cushions and prevent jar The brickwork might also be carried up two or three layers higher than is shown, this would keep the supports of bearings much more firmly, and lessen the cost of the iron, the expensive part It need hardly be pointed out that the passage from the thermantidote has to be suited to the form of building in each case In the case shown, there is doubtless some loss of velocity, but this could not be helped, the height of passage being fixed by the levels of the verandah and main building Were the plinth very high indeed, the fans should be turned over so as to work in the opposite direction as in *Fig* 1, the cover in this case would be partly curved, partly straight If the plinth be very low, the form would be very similar to the drawing, the only exception being that the outlet instead of being curved upwards would turn out straight as in *Fig* 2

Fig 1

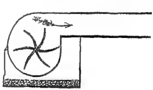
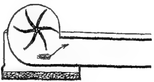


Fig 2



The work in first thermantidote was carried out from rough sketches, and though there are defects, some of which are pointed out above, it worked very well, as the following results will show I have therefore shown it as actually constructed

It was working at one end of a ward 82 feet long, 24 feet wide and 24 feet high, so there was ample room for the stream to disperse, it nevertheless blew out a candle at a distance of 60 feet from the mouth,

it put the whole of the heavy English counterpanes in motion, which were on the beds distributed over the room, it blew a large sola topee a distance of 25 feet, in fact it gave a breeze all over the room. On trial it was found that the action was so easy, that it required only the slightest pressure to put it in motion, and after working it hard for a few seconds and letting go the handles, it continued revolving 17 times.

It may perhaps be noted that no arrangement is made for the khus-khus tattie, this it is thought unnecessary, in an ordinary thermantidote the tattie is pressed close up to the air inlet. This it is believed, is a great mistake as lessening the inlet area, were this area lessened from a circle four feet in diameter, as in the accompanying *Plate* XLIX, to one a foot in diameter, the mistake would be at once apparent, and yet the common custom above noted is just such a mistake, as the only inlet for the air is between the fibres of the grass, lessening the required area to perhaps an even greater proportional extent. What is recommended is to have a cold air chamber on either side as capacious as possible. This can be managed by having the tatties made in the form of a box without a top, kept in place against the sides of the thermantidote by struts, and fitting closely all round, the face tattie should be as large as possible, 7 or 8 feet square, and kept away from the thermantidote by the side tatties, as far as possible, one foot being a practicable distance in this case. This would give a total area of 70 or 88 square feet of grass for the air to be drawn through. The spindle is made of such a length that there is ample room on either side to fit a multiplying wheel, but this it is thought unnecessary, with a rope fixed to the handle and the cooly simply pulling when the handles comes into a vertical position, 30 pulls a minute (a number the laziest cooly would work to) would give a velocity to the outer edge of the faces of over 9 feet a second. A large machine moving slowly is, it is thought better, than a small one at a high velocity, as it distributes the stream of air better.

H. B.

NOTE.—The writer, who is at present living at Sahibgunge, *via* Sickree Guley, will be happy to answer any references.

No CCVIII

PATENT COMBUSTIBLE DAMPER FOR BULL'S KILNS.

[*Vide* Plate L]

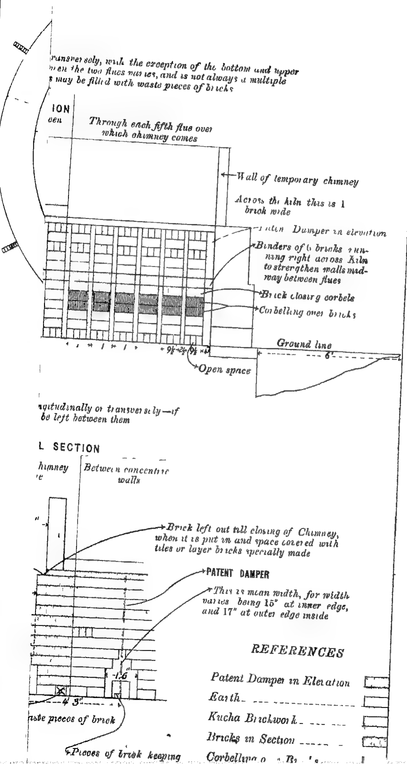
BULL's Patent Kiln is now very generally known, as the numerous applications for licenses, and enquiries as to its working, testify, and as once taken up, it is generally adhered to, any improvements, either lessening its cost, simplifying its working, or increasing its working powers, will it is thought, be of general benefit In the October 1875 number of the Roorkee Professional Papers,* an Article was published on a modified form of the kiln referred to, which has been adopted in several places with success Since that Article was written, an addition has been thought of, which, whilst necessitating a much lower kiln, (a point however in its favor, as the loading is thereby rendered more easy, and the cost of kiln is considerably lessened,) gives just as quick, though much surer outturn, and lessens the consumption of fuel considerably This is a combustible damper, consisting of a sheet of the coarsest cloth, with the coarsest paper pasted on to it, to render it as air proof as possible. It runs up through the middle of a flue as shown in longitudinal section, and reaches to either side, against which it is kept by a brick in every second or third layer being placed up to the walls Between this and the firing the chimney comes, and all openings between the damper and the firing being closed, the chimney cannot possibly draw except from the fire The damper need not of necessity be as close to chimney as shown in drawing, *as long as all openings between it and firing are completely closed*, but loading being well ahead of firing (at least 25 flues), one should be placed near each second chimney space, so that at each alternate move of chimney (spaces for which are left at each fifth flue) the damper will be five flues away from chimney, when a greater distance off

* No. CLXXIV, No 18, Vol IV, Professional Papers on Indian Engineering, Second Series

than this, then action fails to a certain extent Though the dampers have a good effect, with even the low brick chimney, it is slight as compared with what they have with the high iron chimnies as described in the former Article Three of the size first described in that Article are ample with the low kiln, a slight modification is recommended, that of making the width at top 20 instead of 15 inches, the same iron being used as before, this increases the area at the top slightly, rendering it more nearly equal to that at the base

Parties using the kiln of the original pattern, have found difficulty in finishing and closing six or even five flues a day with eight flues being fired, but the writer of this has with the greatest ease for an extended period, been able to close seven flues a day, with two flues being fired fairly hard, two very easily indeed, and two in doorways only, *the average consumption* per lakh on 20 lakhs fired from the end of October, through the cold weather, to the end of March, being 3,057 cubic feet of wood, averaging five inches in diameter, and 466 cubic feet of branches, averaging one inch in diameter, or—allowing four cubic feet of former, and ten cubic feet of latter, to the maund—810 maunds At times during the cold weather, it was found impossible to get the loading done as fast as the firing Before describing the new method of working, the principle will be explained on which the success in working depends This has been arrived at, after prolonged thinking, and after number of experiments, both on ideas of my superior officers, and my own, as to utmost capacity of the kiln, both for burning bricks as well as tiles, and of the best method of loading and firing them The supposition is started with that a considerable length of kiln has been fired, for it is only just at starting that this is not the case Say we have a length of 100 feet fired and finished, we have then a large stock of heat to help us, and the object is to draw this forward into the still unfinished bricks in the most *useful* manner Now whilst this back heat is drawn nearly horizontally forwards by the powerful draught of the chimneys assisted by the damper, it naturally tends to travel at as high a level as possible It can be readily understood that whilst this back heat will raise the unfinished bricks, into which it is drawn, to a considerable temperature, it cannot raise them to quite its own temperature, it is necessary therefore to get some help from the fuel for even the very topmost brick In the same way that the back heat is drawn horizontally forward, the heat (and consequently the flame) from the fuel itself is drawn

LNS


ransversely, with the exception of the bottom and upper
ween the two flues varies, and is not always a multiple
s may be filled with waste pieces of bricks
ION
een
Through each fifth flue over which chimney comes
Wall of temporary chimney
Across the kiln this is 1 brick wide
Damper in elevation
Binders of 6 bricks running right across Kiln to strengthen walls mid-way between flues
Brick closing corbels
Corbelling over bricks
Ground line
6'
Open space
ngitudinally or transversely—if
be left between them
L SECTION
himney
Between concentric walls
Brick left out till closing of Chimney, when it is put in and space covered with tiles or layer bricks specially made
PATENT DAMPER
This is mean width, for width varies being 15" at inner edge, and 17" at outer edge inside
1'6"
4' 3"
aste pieces of brick
Pieces of brick keeping
REFERENCES
Patent Damper in Elevation
Earth
Kucha Brickwork
Bricks in Section
Corbelling o... B...

and only a small proportion of them reaches the top bricks There is no difficulty whatever in getting the lower bricks well burnt, as they get by far the greater effect of the intense heat of the fuel, in addition to a proportion of the back heat travelling forwards The object is to so arrange the firing, that whilst the lower bricks are thoroughly heated by the intense heat of the burning fuel, with a small proportion of the back heat, the upper bricks are similarly heated by a large proportion of the back heat, and a small proportion of the intense heat of the fuel I use the word *intense* purposely, as though the heat *given away* by the fully burnt bricks is very great, that from the fuel is much greater To reduce this to practice—if after unloading, it be found that the lower bricks are underburnt, fire harder, by either feeding *more fuel* into each flue, or by firing *more* flues, if the upper bricks are underburnt, feed less fuel into each flue, or fire fewer flues

As a help to those who have had little or no practice in brick burning with the Patent Kiln, rules will now be given for starting and carrying on the operations, recapitulating to a certain extent what has been written in the former Article

Build a wall across the kiln 4 feet high, 2 or $1\frac{1}{2}$ feet thick, and midway between two flues, leaving four or five openings at base six inches square Load at least 20 flues, leaving a chimney space at the 15th flue, and afterwards at every 5th flue The time of covering in with earth is not of much consequence, so it is recommended to cover up to the first chimney before firing, set up chimneys at 15th flue, damper being just beyond, and a damper at every 10th flue or second chimney space in advance, if there be no fear of the firing proceeding faster than the loading, but if there be, at every chimney space, fire the first two flues—three hours after, two more—three hours after, two more—leave all flues open till they have well taken fire, then close with the earth dummies and plaster round them with mud, opening them for firing only, never close the openings in cross wall at all. Fire fairly hard Nos 1 and 2 when the bricks are well heated, but Nos 3 and 4 very easily indeed, with the exception noted below, Nos 5 and 6 with the fuel not thrown into kiln, but partly in doorway itself, and partly in kiln In all flues, fire as hard as possible against sides of kiln, putting the largest and best pieces with their length say three-quarters in kiln and one-quarter in doorway When the bricks in No 1 flue are at a perfectly white heat, close the

side dummies altogether, having taken care to put one of the largest logs in doorway as explained above Open No 7, and treat as No 6 has been treated (a little burning fuel can be drawn from one of the flues to start the fire in each case), treat No 8 as No 2, and No 5 as No 4, and continue this system throughout, the first two flues being always fired fairly hard, the next two very easily, the next two in doorways only When No 2 is ready for closing, burn the damper and remove the chimnies to next chimney space, but some hours before this, the bricks between No 1 and No 2 chimney should have been slightly heated, by two or three flues in each set of five being slightly fired with small stuff, so as to drive out the steam, which may be allowed to escape from the chimney opening between the two dampers, the flues next to the dampers should not be fired, or there is fear of their getting burnt before their time The object of this is to avoid stoppage of draught when the chimnies are moved, and have between them and the firing a mass of cold, damp bricks for the draught to work its way through

Always take care to have every opening closed between damper and firing, not omitting the top Move the chimney again when the farthest firing flue from it is 15 flues off, and continue this

When No 31 flue has been closed, open No 1 flue for draught, when No 32, No 2, and so on, all the back flues beyond 30 from the firing being kept open, if at any time the draught seems slack, open the 20th back flue from firing, if this does not effect a cure, open the 10th or even the 5th, if the draught cannot be established, (a most improbable contingency,) close these odd ones again, one by one, as the draught increases, the 5th first, the 10th next, and so on

When 50 flues have been closed, knock down cross wall and commence unloading, but never let the unloading approach nearer to the firing than 50 flues

If tiles are to be loaded, they should take the place of the 2nd, 3rd and 4th layers from the top brick flat The rows of tiles need not be coincident with those of the bricks, and they should be apart an *average* distance of $1\frac{1}{2}$ inches, the tiles requiring the least burning, being at sides of kiln, but at least four inches away from them When tiles are loaded, the longitudinal rows of the top bricks should be set six inches apart, or such a distance that a brick will just span from the centre of one to the centre of the other.

The average percentage on the 20 lakhs above-mentioned was 70 of 1st class material,* and 93 of 1st and 2nd class or serviceable tiles, the principal loss on the latter being due to over-firing The fully burnt bricks measured $9\frac{5}{8}'' \times 4\frac{11}{16}'' \times 2\frac{3}{4}''$—the tiles were large 15" Allahabad pattern It will perhaps be observed that whilst the percentage of 1st class material is not high, that of the 1st and 2nd class tiles is very high indeed In burning tiles, the bricks must to a certain extent be sacrificed for them, as if the bricks next the tiles be only slightly overburnt, the tiles are sure to be bent and worthless, the reason for making the sacrifice being that the kucha material of the former costs only one-sixth or one-seventh of the latter When only bricks are to be burnt, an even lower kiln is recommended, say $4\frac{1}{2}$ feet In the former Article, the plan is recommended of dropping down charcoal on to the binder bricks through earthen pipes, set at the top of the kiln A plan just as effective and much cheaper is cutting up thin branches into short traight pieces, and dropping them in the place of the charcoal The regular firemen can cut the branches up when not employed in firing

The cost of the kiln five feet high should not be more than Rs 250 This with the royalty of Rs 250 on the kilns, is 3 annas a thousand on 30 lakhs, which at a low estimate can be outturned in one season

In the original plan of working, not less than 5,000 cubic feet of wood are used per lakh, and putting a maximum expenditure of 3,800 cubic feet (the example noted above shows only 3,523, a large proportion of which was only branches) on the method of working with the damper, there is a saving of 1,200 cubic feet, which at Rs 8 (an ordinary rate) per 100 cubic feet, amounts to Rs 100 per lakh, or one rupee per 1,000

The dampers with royalty cost 3 annas per 1,000, so that the actual saving in using them is 13 annas per 1,000

In an ordinary flame kiln, the average expenditure is 6,000 cubic feet

of wood, and 35 maunds charcoal, costing at the rates of Rs 8 per 100 and one rupee per maund, Rs 515, or per thousand, Rs 5-2 The cost of fuel by the method here proposed is Rs 3 per 1,000—adding to this the cost of kiln and dampers of 6 annas, (3 annas for kiln, 3 annas for dampers,) makes a total of Rs 3-6, or Rs 1-12 less than the cost in ordinary flame kiln No account is taken in this of the cost of an ordinary flame kiln To outturn 30 lakhs in a season, at least four kilns would be required, costing Rs 200 each, or Rs 800 the four This is about 4 annas a thousand on the 30 lakhs, or actually more than cost of a patent kiln with royalty Referring again to the damper—the saving caused by them is so direct as to show itself in even preliminary operations A stock of fuel must be laid in before operations commence, and instead of purchasing 5,000 cubic feet of fuel, at a cost of say Rs 400, 3,800 cubic feet cost Rs 284, and five dampers costing Rs 19, total Rs 303, is all the need be procured per lakh of bricks required

The Agent for the Patents is Mr A H Bull of Sahibgunge, E I Railway, brother of the patentee, to whom all references should be made, which will be promptly replied to

H B

AGRA,
6th April, 1876

No CCIX

CONCRETE BRIDGES

By Lieut -Col H A Brownlow, R E, *Supdg Engineer, Irrigation Branch, Punjab*

Abstract of Report on Construction of Concrete Bridges in the 3rd Division, Bari Doab Canal

The following notes have been almost entirely taken from a report furnished by Mr J Doyle Smithe, Executive Engineer, 3rd Division, Bari Doab Canal

The report was a long one, and gave much information possessing merely a local interest, but scattered through it were the results of Mr Smithe's experience on works in which I had taken very much interest The abstract was made at first entirely for my own use, and it afterwards occurred to me that with a few additional remarks, it might be useful to the officers of the Irrigation Department in the Punjab I have now been asked to let it appear in the Professional Papers, but I am very unwilling that it should do so, without my mentioning prominently the name of the officer who really gathered the experience, and to whose watchful supervision the success of the works is entirely due

Kunkar for Lime —Beaten and screened from earth, burnt in clamps with *úpla*, or in kilns with charcoal, latter method being preferable if charcoal can be obtained at reasonable rates

Kunkar Lime —Picked free from ashes if burnt in clamps, beaten with *thapís* on a brick floor, and unburnt pieces picked out, ground *dry* under an edge stone in a common mortar-mill, then laid in a layer over the ballast. A small proportion of súrkhí or fat lime may be mixed with it (according to the nature of the kunkar) if thought necessary to improve the quality of the mortar

Kunkar for Ballast.—To be beaten and broken to gauge, screened

washed and thoroughly soaked, gauge $\frac{3}{4}''$ for foundations and superstructure, size of large pea for arches

Proportions of Concrete—

One measure of lime to three of ballast for foundations

One measure of lime to two of ballast for superstructure and arch-work a very full allowance of lime being given for arch work all measured dry

Mixing the Concrete.—About 300 cubic feet of cleaned and soaked kunkar spread in a layer about 6″ thick at the bottom of a brick-lined tank, the proper proportion of lime spread over it, and the whole turned over with phaoras until thoroughly mixed

Proportion of Water.—As the mixing of dry lime and ballast goes on, water is sprinkled over the whole, until it appears a moist crumbly mass Best proportion of water is about one-third of volume of lime, or, roughly a mussuck of water to three cubic feet of lime, taking the mussuck to contain one cubic foot Much water fatal to consolidation

Ramming the Concrete.—Immediately after being mixed, the concrete is removed and rammed into the work with cast-iron rammers weighing about 10 lbs each, thrown in layers not exceeding 3 or 4 inches in depth, and rammed down to about 2 or $2\frac{1}{2}$ inches One man will ram from 10 to 15 cubic feet in the day,—total cost of ramming Rs 2 per 100 cubic feet of finished work, 100 cubic feet loose concrete rammed into 50 cubic feet in block-making, 100 cubic feet loose concrete rammed into 55 cubic feet in foundations and superstructure, 100 cubic feet loose concrete rammed into 66 cubic feet in arch work

Pick up surface of a dry layer before putting on another, and keep all surfaces thoroughly cleaned The best test of soundness of work is to pick a hole through the uppermost layer of the concrete and pour water in from a mussuck Properly rammed concrete should retain the water perfectly

Ram concrete in arches with the ordinary iron rammer of 10 lbs, *thúpís* and mallets do not consolidate it sufficiently.

Rammed concrete to be kept covered with water until it has set hard

Face Boards.—When rammed *in situ*, outside shape given to the concrete by strong planking, cut or bent where necessary to required curve, and supported on outside by solid pillars of bricks laid in mud. Two 9″ planks, 2′ or $2\frac{1}{2}''$ thick, fastened together on outside by battens, will make

a sufficient depth of mould board. They should be moved up 15″ at a time, leaving 3″ at bottom to cover edge of last course.

Centrings of Arches.—Should be very strong and substantial. In 3rd Division, Bari Doab Canal, they were made of timber resting on sand cylinders, but where timber is dear, might advantageously be made of earth well rammed between walls of kucha pucka masonry in the manner so common in this country. But even in this case, common kurries should be laid close together upon the top of the earthen centring to distribute the shock of ramming the concrete, and every third or fourth kurrie should project about 3 or 4 feet beyond the face of arch to allow of struts being fixed for support of face boards. Centrings should not be struck or removed until the arch has set quite hard.

Concrete Blocks.—If the requisite amount of supervision can be given to their manufacture, Mr. Smithe thinks that concrete blocks are cheaper and more trustworthy than concrete rammed *in situ*, considering that they save much time in fixing face boards and scaffolding, and prevent any scamping of the work. But I cannot agree with him in preferring them. They require much care, in making and moving, are very apt to get broken, and have the corners knocked off. If used for face work only, and of small size, they are apt to get displaced by the ramming of the concrete behind them. If large and heavy, they give much trouble in moving and laying accurately, while in any case, unless the moulds are most carefully and strongly made, they soon get so much out of shape as to render true building most difficult. The amount of supervision required for blocks would, if given to concrete rammed *in situ* ensure most superior work of the latter kind. The best size for blocks if used is $2' \times 1' \times 1'$.

Method of ramming Arches.—Mr. Smithe considers experiment necessary to prove which is best method of ramming arches in—(1), horizontal layers, (2), concentric rings, or (3), voussoirs. My own opinion is *most strongly* against ramming in horizontal layers, and in favour of adoption of either of methods (2) or (3).

Vibration being the great agent of destruction with concrete arches, it will always be better to have rather an excess of lime than a deficiency, so as to ensure every piece of ballast being entirely embedded in mortar.

The thickness of a concrete arch should be somewhat greater than that

No CCX

DESIGN FOR CANNING COLLEGE, LUCKNOW

[*Vide* Plates LI to LVI.]

By Teekaram, *Head Draftsman, Engineer-in-Chief's Office, Rajpootana State Railway*

Description

This College is designed in accordance of the instructions of the Canning College Committee The character of the building is general keeping with the architectural features of Kaisur Bagh and Saadut Alli Khan's tomb The details have been taken from some of the best known and admired types of Indian buildings The aim of the designer has been to design a building as nearly as possible correct in style and detail, of strictly oriental character

The accommodation consists of one centre or examination hall 100′ × 45′, on left side of which is a library room $47\frac{1}{2}'$ × 28′, and two rooms each $24\frac{1}{4}'$ × 22′, one for the Principal, and the other for an office On the right side there are four rooms, each $24\frac{1}{2}'$ × 22′, one for a European, the other for a Native, Professor, and the other two for graduates, and eight class rooms The rest of the class rooms are provided at the back, and a passage 10 feet wide separates them from the examination hall and the other rooms

A verandah 10 feet wide is provided all round the building, in the corners of it, it is contemplated to place bath and store rooms These rooms are carried out into *baradarees* on the upper story,—there is also a large carriage porch at the front of the building, and another porch at the back A passage 10 feet wide connects the examination hall with

the porch, and two small porches are provided on either side opposite the corridor or main passage

Specification

Excavation.—The earth to be excavated until a thoroughly firm and secure foundation is obtained All inequalities to be dressed off, and the whole made perfectly level, both longitudinally and transversely

Concrete in foundation.—A bed of concrete two feet deep, composed of two parts of broken stone and one part of mortar thoroughly watered and rammed in 6 inch layers, is to be provided under all walls The bed of concrete is to extend six inches beyond the footings of foundation on each side

Masonry in foundation.—The masonry or brick over the concrete is to be built of the best description manufactured at Lucknow, and properly and securely bonded

Superstructure.—The superstructure is to be of the best brickwork in lime mortar To be built to the shape and the dimensions shown in the drawings, the masonry to be carried up at an uniform level, and every course to be carefully levelled, and the face of the walls to be truly vertical

The bricks to be laid with close joints in the best mortar procurable in Lucknow The bricks to be thoroughly soaked in water *before laying*

Every day's work to be flooded in the evening, the tops of unfinished walls to be at all times kept covered with water until they are finished

The pillars of the four corner *baradarees*, the *oriel windows*, and the upper *chutree*, the *balcony* of tower and *chujjás*, to be of sandstone properly dressed and carved, procurable from either Mirzapore or Agra, or any other convenient place

Steps to be of large pucka bricks well burnt and properly shaped, and laid on edge in fine lime mortar *with close* joints The surface is not to be plastered

Plaster and white washing.—The whole of the interior and exterior walls, including domes, but not the stonework as above described, to be plastered. The plaster to consist of four parts of best kunkur lime mixed with six parts of fine stone lime, and the whole well ground in a mill. The plaster to be laid on as follows —The joints of the masonry to be first raked out cleaned and well wetted, the mortar to be then laid with force on the wall so as to fill in the joints fully, without leaving any interstices, and the

plaster then to be floated on in a layer of $\frac{1}{2}$ to 1 inch in thickness, well wetted and beaten, and worked to a proper face, free from all blemishes and blisters Over this a thin coat of fine lime mortar (*sundla*) made of equal parts of the best kunkur and stone lime, and well ground, to be floated on, and properly rubbed to an even surface, on this surface when dry, three coats of fine whitewash, made of pure stone lime is to be given, and finished with an enamelled surface to imitate polished marble

Vaulted Roof of Examination Hall and Library, &c—To be of large bricks laid in best lime mortar, carefully radiated and summered, and to be furnished with wrought-iron tension rods as shown in drawing The skew backs or springing courses to be of *Chunar* stone A khoa terrace three inches thick, well beaten, to be given over the top of the roof. The roof of upper verandahs, both sides of hall, four corner baradarees and towers, to be arched, as specified for examination hall, without tension bar and Chunar stone springing courses

Flooring—The floor to consist of well burnt flat square tiles 12″ × 12″ × $1\frac{1}{2}$″ carefully shaped and laid in fine lime mortar with close joints, and the whole rubbed smooth and fair, and the flooring tiles to rest on nine inches of concrete well rammed

Flat terrace roofing—to be composed of six inches of concrete (to be beaten to four) over two layers of 12″ × 12″ × $1\frac{1}{2}$″ good pucka tiles, set in fine lime mortar, the upper layer of tiles breaking joints with the lower one The tiles to rest on joists on beams, the former one foot apart from centre to centre, and the latter varying from 4 feet to 5 feet 10 inches

The struts and straining beams to be of the dimensions shown on drawing

Doors and Windows—Doors to be made of sál wood in two leaves, framing $2\frac{1}{2}$ inches thick, to be glazed and panelled as shown on the drawings Each leaf to be hung with four-inch butt hinges, to 5″ × 5″ sál wood frames

Framing of windows to be two inches, hung with three-inch butt hinges, to 4″ × 4″ frames

Doors and windows to be provided with proper bolts and fitting, and to be painted with three coats of the best oil color

Cornice, &c—Cornice mouldings and ornamentations of exterior and interior, to be done in the best lime plaster, finished neatly to the exact shape shown on drawing

Railing.—Railings are to be provided for the upper front doors, partly of wood, and partly of wrought-iron, the whole to be painted with three coats of the best oil color.

Ventilators.—Galvanized iron ventilators will be provided for each room, all ventilators should be covered by wire netting to keep out birds, &c.

Skylight.—Glazed skylights to be provided for light and ventilation as follows:—

One large in Native Professor's room.

Six small in corridor.

Painting and Varnishing.—All the woodwork, sunshades, doors, windows, &c., &c., to be painted with three coats best oil color.

Fireplace.—To be constructed in the rooms as shown on the plan, with flues nine inches square, and the chimney shafts above the roof to have openings for egress of smoke, and the inside of the flue to be packa plastered smooth and even, so as to leave no crevices.

Sunshades.—Wooden sunshades will be provided and fixed over the clerestry ventilating windows as shown on drawing. Cast-iron pipe six inches diameter, to carry the rain water from the upper roof to the ground, is to be provided.

Woodwork.—All the timber used in the building to be of the best *sál* wood, sound, and well seasoned, and free from shakes, sapwood, large knots, and all other imperfections to be squarely and evenly sawn, and to be finished to the exact dimensions shown on drawing.

The scantlings of the beams, &c., as follows:—

Beams for room 22 feet, span 5 feet from centre to centre,	12″ × 10″
Struts and straining beams for room 22 feet, span 5 feet from centre to centre, ..	7″ × 7″
Beams for 24 feet 8½ inches span, 5 feet 10 inches from centre to centre, ..	13″ × 10″
Struts and straining beam for 24 feet 8½ inches span, 5 feet 10 inches from centre to centre, ..	8″ × 8″
Beams for 28 feet 7 inches span, 5 feet 10 inches from centre to centre, ..	14″ × 10″
Struts and straining beams for 28 feet, 7 inches span, 5 feet 10 inches from centre to centre,	8″ × 8″
Beams for 20 feet span, 4 feet from centre to centre,	12″ × 9″
„ 13 „ 4 „ „	10″ × 7″

Burghas for span of	5 feet,	1 foot from centre to centre,			$2\frac{1}{2}'' \times 3\frac{1}{8}''$
,,	5 ,,	10 inches	,,	,,	$2\frac{1}{3}'' \times 3\frac{1}{2}''$
,,	4 ,,	10 ,,	,,	,,	$2'' \times 2\frac{1}{2}''$
Kurrees ,,	10 ,,	10 ,,	,,	,,	$3\frac{3}{4}'' \times 5\frac{1}{4}''$

Abstract Estimate

c ft		RS
25,308	Concrete in foundation, including excavation, at Rs 11 per 100,	2,783
54,554	Packa masonry in foundation, at Rs 16 per 100, ..	8,729
32,090	,, ,, in plinth, at Rs 18 per 100, ...	5,778
1,99,051	,, ,, in superstructure, at Rs 24 per 100, ...	47,772
9,553	Arched roof, at Rs 30 per 100, ...	2,866
11,113	Vaulted roof of Examination Hall and Library, including centring, at Rs. 65 per 100, ...	7,223
s ft.		
1,82,402	Pucka plaster, at Rs 4 per 100, ...	7,296
23,752	Tiled flooring, at Rs. 10 per 100, ...	2,375
20,010	Terrace roofing, at Rs 12 per 100, ...	2,401
8,024	Doors and windows, at Rs 1 per foot, ...	8,024
c ft.		
2,259	Chunar stone, at Rs 0-14-0 per foot, ...	1,977
1,707	Sandstone, at Rs 2 per foot, ...	3,414
No		
68	Sandstone pillars, at Rs 10 each, ...	680
c ft.		
4,788	Sál wood, at Rs 1-12-0 per foot, . . .	8,379
r ft		
32	Large cornice, at Rs 2 per foot, ...	64
829	Small cornice, at Rs 0 6 0 per foot, ...	311
s ft		
211	Hand railing, at Rs 0-12-0 per foot, ...	158
No		
52	Ventilators, at Rs. 1-0-0 each, ...	52
1	Large skylight, at Rs 20, ...	20
6	Small skylights, at Rs 8 each, ...	48
38	Sunshades, at Rs 3 each, ...	114
r ft		
880	Cast-iron pipes, at Rs 0-12-0 per foot,..	660
Mds srs		
63 37	Wrought-iron tension bar, at Rs 13-0 per maund, . .	831
No.		
3	Gilted copper pinnacles or cullis for upper chutree, at Rs 60 each, ...	180
	Carried forward, ..	1,12,135

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Out Offices

	Brought forward,	1,1
c ft.		
854	Concrete in foundation, at Rs 10 per 100,	
5,992	Pucka masonry, at Rs 16 per 100,	
s ft		
2,885	Pucka plaster, at Rs 2 8 0 per 100,	
1,022	Terrace roofing, at Rs 11 per 100,	
110	Batten doors, at Rs 0 8 0 per foot,	
c. ft		
145	Woodwork, at Rs 1 8 0 per 100,	
	Total,	1,1
	Contingencies, at Rs 5 per cent,	
	Grand Total Rupees,	1,1

The above is the Specification and Estimate of the Design (illust in *Plates* LI to LVI) which was chosen and approved by the Comn appointed to select a design for the New 'Canning College' at Luck from among a large number which had been submitted by competito accordance with an invitation issued by the Committee

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